PARENTAL TIME AND CHILDREN'S OBESITY MEASURES:

A THEORETICAL AND EMPIRICAL INVESTIGATION

A Dissertation

by

WEN YOU

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

December 2005

Major Subject: Agricultural Economics

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ABSTRACT

Parental Time and Children's Obesity Measures:

A Theoretical and Empirical Investigation. (December 2005)

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Co-Chairs of Advisory Committee: Dr. George C. Davis
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The increased prevalence of childhood obesity is a major concern for society. This study aims at exploring the influence of the parents (especially parental time allocation choices) on children's obesity-related health outcomes and examining the potential differences between the fathers' and the mothers' marginal effects.

A household with two parents and one child is modeled. The household production theory and the collective household modeling structure are combined. The model treats the mother, the father and the child as three separate agents with individual preferences. The two parents' interaction is modeled within the collective model framework by assuming that they will reach Pareto efficient resource allocation between them. In order to capture the dynamics between parents and the child, parents-child interaction is modeled in a two-stage Stackleberg game structure where the child is allowed to have certain decision choices of his/her own. This game structure allows us to explore the parental influence on the child's health outcomes while allowing the child to have influencing power in the household decision-making process.

Based on this theoretical model, a general triangular system with one child's health production equation and five health inputs demand equations is derived and estimated. The empirical estimation is performed for three systems: pooled model, the younger children model (of age 9 to 11), and the older children model (of age 13 to 15).

The empirical results show mother-related variables show more influence on the child's Body Mass Index (BMI) outcomes compared to father-related variables: mothers' BMI and mothers' work-to-home stress spillover are positively related to their children's BMI while mothers' time spent with their children is negatively related to their children's BMI. There exists a complementary relationship between mothers' income and fathers' food preparation time. In the older children model, mothers' own income increases tend to decrease their time spent with their children.

The main contribution of this study is that it develops a general theoretical framework to capture the dynamics in parents-child interaction. Based on this theoretical model, empirical analysis and future work can be conducted in a theoretically consistent way.

DEDICATION

To my husband, my son and my parents

ACKNOWLEDGMENTS

I must first thank my committee chairs Dr. Davis, and Dr. Nayga for their guidance and support throughout the course of this research. I especially want to thank Dr. Davis who always encouraged and inspired me to pursue this topic and who guided me with outstanding wisdom and extreme patience. I really appreciate Dr. Nayga's encouragement and comfort during the whole process and Dr. Mitchell's constant guidance. I would like to thank Dr. McIntosh for providing me the opportunity to work on the project and to get to use the unique data set in this study. I would like to thank all my committee members for their support and their time in reading this dissertation.

Special thanks to the great support from my colleagues and the department faculty and staff.

Finally, thanks to my husband, Dawen, who has always been there for me. I could not have gotten to this stage without his unconditional love and support. I would like to extend my appreciation to my son. Without his constant "massaging" in my tummy, I would not have been able to have enough energy to finish this work.

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CHAPTER I

INTRODUCTION AND MOTIVATION

1.1. Obesity Epidemic

Overweight and obesity are among the most pressing health challenges today and may soon cause as much preventable disease and death as cigarette smoking (US DHHS 2001a). Obesity is a growing concern in both developed and developing countries. New figures from the World Health Organization (WHO) indicate that obesity is spreading around the world as a "global epidemic." According to WHO, globally there are more than 1 billion adults who are overweight and at least 300 million of them are clinically obese (WHO 2004).

In the United States, nearly one-third of all adults are obese and 15 percent of children and teens aged 6 to 19 are overweight (US DHHS 2002).[1] Childhood obesity is becoming a major concern in the United States. An estimated 14% of children between the ages of 6 and 17 have a body mass index (BMI) for their age that is indicative of at-risk for overweight; an additional 11% have a BMI for their age that is considered to be overweight (Troiano and Flegal).

This increased prevalence of childhood obesity is a major concern for our society because obese children will likely become obese adults and many adult health problems, such as diabetes and heart problems, are associated with obesity. Therefore, the economic costs of obesity are significant. From 1979 to 1999, annual hospital costs for

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This dissertation follows the style of *American Journal of Agricultural Economics*.

[1] The preferred term in addressing excess weight in children is overweight.

treating children's obesity-related diseases rose from $35 million to $127 million (Wang and Dietz). The average obese adult spends nearly $400 more per year on medical expenses compared to a healthy-weight adult (Sturm). Nationally, the U.S. Surgeon General estimates that the annual cost of overweight and obesity is nearing $117 billion (US DHHS, 2001b).

1.2. Changes in the Parental Time Allocation

The factors affecting the childhood obesity are many and not well understood. In the standard nutrition literature, obesity is a function of the balance between energy intake and energy expenditure (Hoffman and Sawaya).[2] Energy intake and expenditure are influenced by genetic factors and environmental factors. One environmental factor that would seem to be important is parental time allocated to their children.

Adult time allocation has changed greatly over the last three decades as more women have entered the labor force. Less time at home and more time at work results in less time available for food preparation and active leisure (Chou, Grossman, and Saffer). Meanwhile, technological changes have occurred in the food sector: the switch from individual to mass preparation has led to increased quantity and variety of food consumed (Cutler, Glaeser, and Shapiro). One would expect that parental decision-making on time allocation could play a significant role in children's physical health production: higher frequency of family meal skipping, declined activity time with their

[2] The details will be presented in the theoretical chapter (Chapter III).

children and increased convenience food consumption will be likely to negatively impact children's diet patterns and lifestyles, ceteris paribus.

1.3. Economic Literature Overview

Unfortunately, the effect of parental time allocation and other parental factors on children's physical health outcomes is an area of research that needs more theoretically consistent study.[3] For many years, the economic framework for analyzing the issue of time allocation and household production, such as nutrient intake and children's outcomes, was based on the unitary household production model.

However, over the last decade major limitations of this model have been recognized and the literature has moved to collective models (Vermeulen). The collective approach and its refinements have mainly focused on modeling household labor supply decision-making (e.g., Chiappori 1997; Apps and Rees 1997). The main empirical focus has been on testing the income-pooling hypothesis (e.g., Bourguignon et al.), which states that the source of income in the household is irrelevant in consumption decisions.

Most work has modeled the behavior of households without children. Some refinements have included children in the model by treating children as public consumption goods for adult household members (e.g., Bourguignon). In terms of child-related issues, some researches have considered the costs of children by treating children as individual household members (e.g., Apps and Rees 2002). Some have explored the

[3] The detailed literature summary will be presented in the next literature review chapter (Chapter II).

impact of fertility or children's health on parent's labor supply decision-making (e.g., Gould; Xie). Recently, several researchers have investigated the effect of parental time allocation on children's overall quality/performance by treating children and parents as separate agents (e.g., Amuwo et al.; Burton, Phipps, and Curtis).

No known studies, however, have examined the effects of parental time allocation on children's physical health. Conceptually, the literature on the relationship between parents and children has not generally incorporated children's own choices into the optimization framework and has worked within a single-headed household model.

This is not a very appealing approach for considering the influencing factors on children's physical health outcomes (especially obesity-related ones) since children have some control over their energy intake and expenditure which are the two key components for obesity-related health production. Furthermore, a single-headed household model, much like the income pooling hypothesis, implicitly treats all time allocated to the children as the same regardless of the source, i.e., the mother's time or the father's time. Consequently, the potential difference of time allocation effects between mothers and fathers cannot be assessed.

Perhaps the main reason for these conceptual limitations has been the lack of data rich enough to consider more sophisticated models. That is, it has been difficult to investigate the relationship between parental time allocation (including market work, housework, time spent with the child and personal leisure) and children's physical health outcomes. The desirable data set should not only include children's health status and nutrient intake information but also have detailed parental time diary records on individual levels. As Haveman and Wolfe pointed out, many existing data sets cannot meet this degree of richness resulting in a “variable scarcity” problem.

1.4. Objectives of This Study

This study aims to explore the influence of parental time allocation choices and other parental factors on children’s obesity-related health outcomes and examine the potential differences between the marginal effects of paternal choices and maternal choices.

A theoretical model that includes children’s obesity-related health production and parental time allocation will be presented. The model treats the mother, the father and the child as three separate agents with individual preferences. The interaction between the two parents is modeled within the collective model framework by assuming that the two parents will reach Pareto efficient resource allocation between themselves. In order to capture the dynamics within household decision-making between parents and children, the theoretical framework will model parents-child interaction in a two-stage game structure where the child is allowed to have certain decision choices of his/her own.

From this theoretical framework, we are able to derive the children’s obesity-related health production function (which is a structural equation from the parents’ point of view). The empirical set up chapter will present this structural equation along with other five reduced form health input equations as a general triangular system for estimation.

This study utilizes a complex data set which fills the gap in the data needs for this type of multi-disciplinary research. The details about the unique characteristics of this data set and the survey instruments are reported. This data set makes it possible for us to explore the individual parental influences and the potential differences between the fathers and the mothers.

Chapter II will summarize the related economic and sociological theory development and empirical findings. The theoretical chapter, Chapter III, will present detailed theoretical model set up and model derivation along with comparative statics results and discussions. Based on the theoretical model framework laid out, Chapter IV will derive a general triangular system of equations and discuss the empirical estimation strategies. The data and summary statistics chapter, Chapter V, will describe this unique data set in detail and discuss the variable generation process and summary statistics for those variables of interest. Chapter VI is the results chapter where the empirical estimation results on the general triangular system will be discussed and summarized. Finally, Chapter VII will conclude the main content and findings of this study and describe future research possibilities.

CHAPTER II

LITERATURE REVIEW

This study focuses on exploring the influence of parental factors on children's obesity-related health outcomes in a theoretically consistent way. The research falls naturally into the area of "household production of health" (HHPH) (Berman, Kendall, and Bhattacharyya).[4] There are numerous combinations of determinants that a household can adapt to maintain a certain level of health. HHPH is a topic being studied by a variety of disciplines: anthropology, social psychology, and economics. Each discipline has its own sets of factors and model frameworks to work on although they do overlap to a certain degree. To conduct a thorough examination on HHPH calls for interdisciplinary quantitative and qualitative research work (Berman, Kendall, and Bhattacharyya; Haveman and Wolfe).

This study incorporates sociological factors into economic analysis so a summary of economic theory framework development and the sociological literature will be presented here. In terms of economic literature, there has been an enormous amount of work done on household behavior modeling both in theoretical development and in empirical applications (Gronau 1986, 1997).[5] However, there is little research on examining the influence of parents on their children's health outcomes. The children's

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[4] HHPH is defined as: "A dynamic behavioral process through which households combine their (internal) knowledge, resources, and behavior norms and patterns with available (external) technologies, services, information, and skills to restore, maintain, and promote the health of their members." (Berman, Kendall, and Bhattacharyya).

[5] The empirical implementation covers labor supply, inequality, costs of children, and children's attainments etc.

attainment literature does explore the influence of the parental choices on children's attainment. But in those studies, the attainment definition does not include children's obesity-related health outcomes and time allocation choices of both parents are not considered as potential determinants. This chapter will summarize the theory development and empirical results that focus on children outcomes and intra-family time allocation.

2.1. Economic Theory Summary

Becker (1965) introduced the household production model (HPM) into the traditional consumer behavior analysis, which began the so-called "new household economics" (NHE). NHE brings together the theories of production and consumption into a more coherent theory of household behavior and recognizes time as a valuable household resource.

In the HPM, households are producers as well as consumers. Households demand market goods and services and then combine them with the household members' own time and capacities to produce the final products desired by the households. One of the household goods produced can be children's health outcomes, which are an obvious source of satisfaction many households would seek to attain. Within this HPM framework, the theory development has gone through several waves of modifications.

2.1.1. Unitary model of children's health outcomes

In the original HPM of Becker, the household acts as a single decision-making unit even though the household consists of different individuals. The original Becker model depicts a single household decision-maker case and the model only considers a two-way time exchange: the household production time and market work time. The single decision-maker will maximize a single household utility function subject to a pooled household budget, household production functions, and time constraint.

Gronau (1973, 1977) expanded Becker's model into a two-person household and introduced a third time use – leisure – as opposed to home production time in general.[6] However, Gronau's model still treats the objective function as a single household utility function.

In order to clearly present the structure difference between the unitary model and the models emerging later on, we will slightly extend the Becker-Gronau model into a multi-person household with two parents and one child. Also, in order to put it into the children's health household production related framework, we limit the household production to only the children's health production.

Let us define a utility function for a household consisting of two working parents (*F*, *M*) and one child (*C*) as:

$$(2.1) \quad U = u(x^F, x^M, y, t_l^F, t_l^M),$$

where u is a strongly quasi-concave, increasing and twice continuously differentiable function in its arguments. There are two vectors of parents' individual private good

[6] See Gronau 1973 paper models a two-person household and introduces the leisure time. His 1977 paper focuses on time allocation and simplifies the model back to depict a single person household.

consumptions, (x^F, x^M), the household produced child's health outcome, (y), and the two parents' individual leisure time, (t_l^F, t_l^M).

The single household decision-maker faces a household production constraint, a household budget constraint, and two parents' time constraints. The household child's health production constraint is defined as:

(2.2) $y = y(m, t_y^F, t_y^M; \mu)$.

The production function has a vector of the child's health production inputs, (m), and the two parents' time spent on the production of household goods y, (t_y^F, t_y^M). There is also an initial endowment vector μ of human capital inputs to domestic production. The production function exhibits positive decreasing marginal productivity.

The pooled household budget constraint is:

(2.3) $p^1 x + p^2 m \leq \sum_i (w_i t_w^i + I^i) \quad i = F, M$.

The vector of market goods x ($x = (x^F, x^M)$) has a price vector p^1, and the household production input vector m has a price vector p^2. The household total income consists of two parents' earned income and unearned income: w_i is the market work wage rate for adult i and I^i is the individual unearned income of member i. The individual i's market work time is denoted as t_w^i.

In addition to the above two constraints, the household decision-maker also faces two individual time constraints:

(2.4) $t_y^F + t_w^F + t_l^F = T$

(2.5) $t_y^M + t_w^M + t_l^M = T$.

Under the assumption of non-satiation, the resulting full income constraint from combining (2.1.3), (2.1.4) and (2.1.5) is:

(2.6) $p^1 x + p^2 m + \sum_i w_i (t_y^i + t_l^i) = \sum_i (w_i T + I^i) = \sum_i w_i T + I$, $i = F, M$,

where the aggregate unearned income I equals the sum of the two individual unearned incomes ($I = I^F + I^M$).

The household decision-maker maximizes the single household utility function (equation (2.1)) while facing the household child's health production constraint (equation (2.2)) and the household full income constraint (equation (2.1.6)). The maximization results in a set of unconditional demand functions for market goods, health production inputs and leisure:

(2.7a) $q = g(p^1, p^2, w_F, w_M, T, I, \mu)$,

where $q = (x^F, x^M, m, t_y^F, t_y^M, t_l^F, t_l^M)$ and g is a vector valued function. After substituting those optimal solutions (equation (2.7a)) back into the children's health production function, we will get the indirect children's health production function

(2.7b) $y = f(p^1, p^2, w_F, w_M, T, I, \mu)$.

These demand functions (equation (2.7a)) have theoretically well-known properties: adding up, homogeneity, Slutsky symmetry, negativity. However, empirical testings of these properties repeatedly rejected them, with the exception of the natural adding up condition (see Vermeulen for detailed references). Another empirical restriction resulting from the unitary HPM is the so-called "income pooling hypothesis" and it has been universally rejected in the literature (e.g. Bourguignon et al.; Lundberg, Pollak, and Wales). The "income pooling hypothesis" states that the household pools all nonlabor income together to optimize the household utility, however, the source of unearned income does not affect the intra-household resource allocation. This restriction also can be shown in the equation (2.7a) where fathers' and the mothers' unearned income demand marginal effects are the same: $\frac{\partial g}{\partial I^F} = \frac{\partial g}{\partial I^M} = \frac{\partial g}{\partial I}$.

These empirical drawbacks give rise to many alternative approaches that realize that different preferences of the household members, as well as the existence of dominance or power relations within the household, are important and should be modeled. These alternative models fall under the heading of non-unitary models.

2.1.2. Non-unitary model (collective model) of children's health outcomes

The emerging alternative approaches all try to take the intra-household decision-making process out of the black box. They treat the household members as distinct individuals with common interests as well as conflicts. These approaches differ in the assumptions imposed on the intra-household decision-making process.

The game theoretical framework is naturally applied to model this complex intra-household decision-making process. Some refer to noncooperative game theory and some utilize the axiomatic bargaining approach (e.g. McElroy).[7] The former describes the household decision-making process as a game between participants, however, the efficiency will not be able to be gained in most cases. The cooperative bargaining

[7] See Vermeulen for detailed references.

approach will certainly lead to Pareto efficient outcomes. However, both approaches impose certain assumptions on the decision-making process which specifically lead to particular equilibrium and the bargaining rules imposed cannot be tested apart from the collective setting (Chiappori 1988).

Instead of imposing a particular bargaining rule, Chiappori (1988, 1992) and Apps and Rees (1988) developed what is called the collective model: they assume only that the household decision-making process will always result in Pareto efficient outcomes. In other words, at the optimal point no household members can gain more without hurting the other members. This Pareto efficiency assumption has been justified as the natural result of repeated long-term games, with the household dynamic as one example (Browning and Chiappori). Apps and Rees (1996, 1997, 2002) and Chiappori (1997) introduced household production into this collective framework. This section will follow their collective model setup to present the framework and contrast it with the above unitary HPM.

The collective method models household individuals with unique preferences. Let us define the two parents' individual utility functions as:

(2.8) $$u_i = u^i(x^i, y, t_l^i) \qquad i = F, M \ .$$

So, the individual adults in the household will gain utility from their own market goods consumption, (x^i), the household produced child's health outcome, (y), and their own leisure time, (t_l^i). This is an egoistic preference setting and can be easily extended to accommodate difference preference assumptions (e.g., caring, Beckerian, etc.). The utility function of the child can be defined on its own market goods consumption, x^C, and the household-produced child's own health outcomes, y:

(2.9) $u_C = u^C(x^C, y)$.

All utility functions are strictly quasi-concave and increasing in their arguments, and at least twice continuously differentiable.

The constraints in the collective model are similar to those in the unitary model presented in section 2.1. Most works using the collective model focus on childless households. A few studies treat children as individual household members (Apps and Rees 2002; Bourguignon). However, they do not model children as contributors in the household production process. Children do not have influencing power over home production and the household decision-making process in those models. So the multi-person household's children's health production function remains the same as the unitary model (equation 2.2). The full-income constraint is also similar to equation (2.6) except the vector of market goods x now has one more component (the child's own market good consumption): $x = (x^F, x^M, x^C)$.

The fundamental difference between the collective model and the unitary model is that the household maximization problem now is modeled in a Pareto efficiency setting: household members will maximize their own utility function while making sure that other members' reservation utility levels are met. The household maximization problem can be presented as:

$$\underset{(x^F, x^M, x^C, t_y^F, t_y^M, t_l^F, t_l^M)}{Max} u^F(x^F, y, t_l^F)$$

s.t.
$$\begin{cases} u^M(x^M, y, t_l^M) \geq \overline{u}^M \\ u^C(x^C, y) \geq \overline{u}^C \\ y = y(m, t_y^F, t_y^M; \mu) \\ p^1 x + p^2 m + \sum_i w_i(t_y^i + t_l^i) = \sum_i (w_i T + I^i) = \sum_i w_i T + I . \end{cases}$$

where $\overline{u}^M$ and $\overline{u}^C$ are the mother's and the child's reservation utility levels, respectively. All Pareto efficient allocations can be traced by varying the reservation utility levels. Apps and Rees (2002) treat children as individual household members with unique own preferences. They assume that the children's reservation utility constraint is not binding and can be ignored.[8] So the Lagrangian of this maximization problem does not have a children's utility function in it.

Based on the assumptions that the individual utility functions are strongly concave and the budget constraint is a convex set, the utility possibility set is strictly convex. So, the above maximization problem can be rewritten as:

$$\underset{(x^F, x^M, x^C, t_y^F, t_y^M, t_l^F, t_l^M)}{Max} U = W(p^1, p^2, w_F, w_M, I^F, I^M) u^F(x^F, y, t_l^F)$$

$$+ [1 - W(p^1, p^2, w_F, w_M, I^F, I^M)] u^M(x^M, y, t_l^M)$$

subject to the production constraint (equation (2.2)) and the household full income constraint (equation (2.6)). *W* and (1-*W*) are positive welfare weights attached to the two

[8] So the weighted household utility function does not have child's utility as one of the components. This formulation does not allow the children to have their own choices to influence the intra-household allocation process.

parents. They are the normalized Lagrangian multipliers from the previous maximization problem and depend on the exogenous variables of the model. They represent the bargaining power of household members in the intra-household resource allocation process. The solutions to this maximization problem are a set of unconditional demands:

(2.10) $q = g(p^1, p^2, w_F, w_M, T, I^F, I^M, \mu)$,

where $q = (x^F, x^M, x^C, m, t_y^F, t_y^M, t_l^F, t_l^M)$.

Now, the sources of the household members' individual nonlabor income are important to intra-household resource allocation. The change in individual unearned income will affect intra-household consumption and time allocation in two ways: the usual income effect through the household budget constraint, and the bargaining power effect through shifting individual welfare weight. The same arguments can be applied to market goods prices and individual market work wage rates.

2.1.3. Other children-related modeling framework modifications

Most work on collective models has targeted either single-person households or childless two-person households. This section will focus only on those works that explore the parental influences on children outcomes (either health or other attainments).

The unitary HPM has a dimension, Becker's "Rotten Kid Theorem", that actually tries to reconcile the unitary model with the fact that households may consist of multiple decision makers. This theorem describes family members' interaction in a household with a benevolent household head and several family members as beneficiaries. It states that the selfish household members will maximize the total household income even without the presence of a pre-committed incentive plan, if the benevolent household head can redistribute the total household income as gifts to household members. In other words, if certain conditions are met, the altruistic parents and their selfish children will all maximize the same utility function. As Bergstrom points out, this theorem still requires transferable preferences and a specific decision process for it to hold true.

However, it is worth mentioning that this theorem is built upon a two-stage “game” (Becker 1981): the children get to choose their behavior in the first stage; then the parents will decide on how to distribute the gifts to their children after observing their behavior (set of children’s action choices). This can be put into standard principal-agent theory language.[9] Cigno, Luporini, and Pettini also introduce the principal-agent framework into children attainment analysis, although they model the government as the principal and the parents as the agents. The incentive model has been utilized in some studies to show parents-child interaction within the family, however, they focus only on the mechanism designs of parental pecuniary and nonpecuniary incentives for inducing child obedience (See Weinberg for detailed literature survey). Burton, Phipps and Curtis develop a model to depict parents-child interaction within the family as a simple mechanism design with certain incomplete information from the child. In their model, the children’s behavior is measured with an index of conduct disorder/physical aggression.

The two-stage game is an intuitive way to treat the parents and the child as separate agents and model parents-child interaction. The literature utilizing the incentive theory

[9] It will be presented in details in the following theoretical chapter (Chapter III).

to model household behavior does not explore the influence of parents (especially the parental time allocation choices effect) on children's health outcomes. This study will actually examine this topic by utilizing a similar framework in part of the theoretical modeling.

The area that has received the most attention is modeling the cost of children. Bourguignon modeled children as public consumption goods by the two adult members of a household. Apps and Rees (2002) treat children as individual household members with their own distinct preferences. However, children are not modeled to have any participation in the household production process, which does not hold true for the children's own health production.

Hallberg and Klevmarken contribute to children attainment literature by emphasizing that, in the collective HPM where children's quality is produced, parental time with children, market work time and parental leisure time are interdependent. They also introduce the "process benefits" concept which first appeared as the time-involved household production and joint production properties pointed out by Pollak and Wachter. This concept stresses that the time spent in an activity may bring direct well-being to the individual independent of the activity outcomes. The implication of this concept is that the utility function should include other time devotion choices as arguments, as well as own leisure time. This study will also model the joint production effects.

2.2. Economic Empirical Results Summary

Haveman and Wolfe have an extended survey of children attainment literature through 1993. In the children attainment literature, a variety of measures have been considered: for example, categorical dummy variables, such as whether the children graduated from high school; and continuous variables, such as children's future annual earnings. However, no works actually look at parental influences on children's health outcomes. Most empirical research does not have a common framework to direct model specification and relevant variable selection (Haveman and Wolfe), which leads to arbitrary choices of variable combinations. Haveman and Wolfe also point out that few studies actually recognize the interdependence among variables and systematically model that interaction.

Recent literature has moved towards modeling parents-child interaction in order to derive a theory-based empirical framework. This section will actually focus on presenting these studies.

Burton, Phipps and Curtis recognize that the previous children's attainment literature does not model the child himself/herself as a participant in the child attainment production process. They develop a simple game to model the two-way interaction between parents and the child. In their model, the parents will choose a "parenting strategy" while considering all the possible actions of the child (child's behavior choices). The parents have incomplete information about the child's mood and the principal-agent framework fits well for modeling this incomplete information. Their theory derivation leads to a simultaneous system of equations with a parenting style equation and a child behavior equation. They do not define the children behavior specifically in the theoretical model and use an index of conduct disorder/physical aggression to represent the child's behavior in the empirical analysis. They define the parenting strategy as an index of punitive/aversive parenting responses. Additionally, their model does not consider parental time allocation choices and children's health outcomes.

The data set they employed is the 1994 Canadian National Longitudinal Survey of Children and Youth (NLSCY). They studied children aged 6 to 11, living in two-parent families. The sample size is about 8,481 children. The endogeneity tests suggest that parenting style is not exogenous to child behavior and vice versa, so 3SLS and OLS estimators are presented. Their results suggest that socioeconomic factors (e.g., family size, age and gender of the child, mother's age) and parenting style are important determinants of child behavior, and that parenting strategy is affected by parent's life stress and the child's behavior.

Weinberg investigates the relationship between parental income and children's outcomes using an incentive model design. In his economic model, children choose their own actions while parents seek to influence these choices through providing pecuniary incentives. He used the data from the Child Development Supplement (CDS) of the Panel Study of Income Dynamics and ran probit regressions of withdrawal of allowance and the use of corporal punishment on a cubic in family income and the characteristics of the child, family and primary caregiver.[10] The results suggest that the parents' ability to mold their children's behavior through pecuniary incentives is limited at low incomes and this leads to increasing reliance on non-pecuniary mechanisms such as corporal punishment.

Most of the economic literature on household behavior modeling does not model children as individual household members. For those that do include children in their models, the children are either public goods for the household adults or do not participate in the household production and have no decision power in the household. Recent approaches start to introduce incentive theory to model parents-child interaction but they do not consider the children's health outcomes and the parents' individual time allocation choices. This study tries to fill this gap by developing a theoretical framework to depict this aspect of family dynamics.

2.3. Sociological Theory and Empirical Results Summary

This study develops a multi-disciplinary model structure that covers both economic factors and sociological aspects of family dynamics. It is important to cover the sociological literature in this chapter and a detailed literature review can be found in the project report by McIntosh, et al.

There are several factors sociology considers in the HHPH: role theory, work flexibility, work commitment, work-to-home spillover, parents' power difference, and heredity.

[10] Withdrawal of allowance and the use of corporal punishment are the two indexes he used to capture the children's behavior.

Role theory in sociology states that there are many socially prescribed roles that individuals take on. Adults may be employee, spouse, parent, etc., while the child may be student, friend, etc. Each role has its own associated standard of fulfillment and demands individual resource allocation to a certain extent. One of the most highly demanded resources is individual time. This has been recognized in economic literature, as discussed in previous sections. When role demands exceed the time and energy resources of an individual, there will be either conflict between different roles or within the same role where partners share the work load (e.g., spouse) (Pearlin).

For working parents, stress can be an important factor affecting behavior. One obvious stress source is work. The sociological literature has found negative emotional and physical consequences associated with work stress caused by work demands that are beyond the employee's ability to handle (e.g. Karlsson, Knuttson, and Lindahl.; Rau and Triemer). Work flexibility and work commitment are also found to be two important causes of this type of work stress. Those employees who have less flexibility in their work schedules (work hours or work days arrangements) are found to have more work stress and health consequences. Their household labor division will also be affected by work flexibility which may tend to create conflicts between spouses. Meanwhile, Laedwig and McGee point out the positive relationship between work commitment and marital conflict. Those who have high work commitment may devote less time and energy to other family members and the quality of family time will be negatively affected.

Also, several other studies suggest that work stress can lead to tension in spousal relationships and have a negative impact on parents-child interaction (e.g. Crouter and Bumpus; Kinnunen, Geurts, and Mauno). This describes another sociological factor in family life: some roles' conflict spills over to other roles (affects the other roles' fulfillment). The most relevant spillover that affects the parents-child and spousal relationships is the work-to-home spillover. Parents' work stress may be carried over into family interactions. The emotional burden, physical exhaustion and overtime work demands will affect marital satisfaction and negatively affect the quality and quantity of parental time with their children.

Work flexibility, work commitment and work-to-home spillovers are all found to affect family eating habits. Devine et al. found that women who have high work stress and experience work-to-home spillover will have greater frequency of skipping meals, eating out and purchasing "junk food" for family meals. However, most of the literature on work stress and spillover health consequences is concerned with the employees themselves, not their family members (e.g., their children).

The sociological literature also shows that the power difference between husband and wife will benefit the one with the higher status (e.g., Blumberg). This suggests the potential linkage between parents' power differences and household decision-making.

Heredity has also been proved to be an important factor in children's intake and outcomes. Several studies (e.g., Agras et al.) have suggested the positive relationship between parental BMI and their children's BMI.

As mentioned before, a lot of research in the field of sociology has focused on health determinants. Within this literature, some have considered children's health outcomes, but they do not specifically analyze parental time devotion effects on children's health outcomes and there is no common framework to guide the empirical variable selection.

2.4. Chapter Summary

This chapter presents a brief summary of related literature on economic and sociological theory development and empirical work.

In the economic field, most of the household behavior studies do not model children as individual household members. For those that do include children in their models, children either are public goods for the household adults or do not participate in the household production and have no decision power in the household. This is not appropriate for modeling children's health production. Recent approaches start to introduce incentive theory to model parents-child two-way interaction but they do not consider the effects of parents' individual time allocation choices on children's health outcomes.

Some sociology studies have considered children's health determinants but they do not specifically analyze the parental time devotion effects and there is no common framework to guide empirical variable selection. Thus, empirical examinations were conducted over sets of arbitrarily chosen potential determinants.

So, although there are huge amounts of related literature in the fields of economics and sociology, this chapter focuses on summarizing only those recent developments that consider children’s outcomes and model parents-child interaction.

This study tries to fill the gap by developing a theoretical framework to depict parents-child two-way interaction in order to explore the influence of parents on children’s health outcomes. The model incorporates both economic and sociological factors and the theoretical model guides the empirical analysis.

The following chapter will present the detailed model structure and derivation.

CHAPTER III

THEORETICAL MODEL

3.1. General Model Set Up

The focus of this dissertation is investigating parental time effects on children's health production outcome, more specifically obesity-related health measures. The theoretical model extends Becker's household production model to a multi-person household consisting of two parents and one child. Also, the model allows each individual to allocate his own time among different activities: parents will be able to decide on time allocation among market work, home production, parents-child activities and other residual time; the child will be able to decide his/her own time allocation among food consumption, exercise and other residual time. Our model differs from those in previous literature by allowing the child to have his/her own choices instead of being treated as a public good (Bourguignon) or as an individual household member without any household decision power (Apps and Rees 2002). Home production is limited to the child's obesity-related health production as this is the focus of our study.

Our model considers a multi-person household with two parents and one child, each with his/her own utility function. We are interested in the interaction between parents and the child, so we model the parents-child interaction as a two-stage Stackleberg game while keeping collective modeling structure within the father-mother interaction. By doing so, we are able to disentangle the individual parent's interaction with the child and the game structure allows us to derive the partial reduced form of the child's health production function with parental time allocation variables as arguments. This enables us to empirically analyze the effect of parental time allocation and other parental factors on the child's health production outcomes.

3.1.1. Defining obesity-related health production function

In order to define the obesity-related health production function and its components, this dissertation follows the nutrition literature. According to Hoffman and Sawaya, the metabolism of nutrients (i.e., energy) in the human body is mainly about energy balance: Energy Intake = Energy Output. As they point out, it follows the First Law of Thermodynamics in that the energy is not created or destroyed within a closed system, but only changes form. The human body is able to store excess energy for usage during an energy deficient period. So the energy balance formula can be rewritten as the following:

(3.1) Energy Intake = Energy Output $\pm$ Energy Stored.

Obesity is "having a fat mass larger than what is considered healthy" (Hoffman and Sawaya) and this links to excess energy intake compared to energy output. So the children's obesity-related health production function should have two main components: energy intake and energy output.

We define children's obesity-related health as *H*, determined by the following production function based on equation (3.1):

(3.1') $H = H(I, O)$,

where I is the nutrient intake measurement and O is the energy output measurement. Hoffman and Sawaya point out that the intake of nutrients is influenced by numerous factors. We define the nutrient intake production function components based on those factors:

1. Food availability. We use the following six variables to capture food availability: child's time spent in food consumption (t_f), child's food input choice made by self (x_f), child's food input choice made by father (X_f^F), child's food input choice made by mother (X_f^M), father's time spent in food preparation (T_f^F), and mother's time spent in food preparation (T_f^M);
2. Palatability. We use t_f and child's type variables (μ, such as gender, ethnicity etc.);[11]
3. Social and family influences. They are captured by five variables: home environment (E_H), peer influences (E_P), child's type variable (μ), parent's type variables (k^i, where $i = F, M$, such as parent's BMI, parents' power difference etc.);
4. Psychological state of the person. We use type variables for the child and the parents (μ and k^i, where $i = F, M$) for this;
5. Composition of a meal. This is depicted by x_f, X_f^i, and T_f^i, where $i = F, M$;
6. Amount of exercise. We use child's time spent in exercising (t_E) as indicator.

[11] In our theoretical model, the child's time spent in food consumption (t_f) will enter child's utility function directly to capture another aspect of palatability: t_f can bring positive utility to the child.

So as defined by the above, we have the following nutrient intake production function:

(3.2) $I = N(x_f, t_f, t_E, X_f^F, X_f^M, T_f^F, T_f^M; E_H, E_P, \mu, k^F, k^M)$.

N represents nutrient intake.

Total energy output (or energy expenditure) has three components. The first two components (basal metabolic rate and thermogenic component) are related to the person's age, gender, state of health and fitness, etc. The last one (physical activity and arousal) depends on the intensity and the duration of the activity involved (Hoffman and Sawaya). We use the following three variables to depict these components: child's type variables (μ), parent's type variables (k^i, where $i = F, M$), and child's time spent in exercising (t_E).

After we have defined the energy intake (I) and energy output (O), the child's obesity-related health production function, equation (3.1'), can be rewritten as:

(3.3) $H = H(N, t_E; \mu, k^F, k^M)$.

N is the energy intake production function, and the other variables capture energy output. Based on equation (3.1'), we combine the two production functions (equation (3.2) and equation (3.3)) for our model. And both production functions are assumed to exhibit non-increasing returns and to be twice differentiable.

3.1.2. Defining the child's own utility function

The utility function of the child is defined on the following components:

1. The child's own obesity-related health production outcome (H);

2. All of the child's time allocation choices: the child's time spent in food consumption (t_f), the child's time spent in exercising (t_E), and the child's other residual time (t_o);
3. Part of the parental time allocation choices: the parent's individual time spent with the child (parent-child time) (T_C^i, $i = F, M$), the parents' joint time spent with the child (parents-child time) (T_C^J);
4. Social and family influences: home environment (E_H), and peer influence (E_P).

So the child's own utility function is:

(3.4) $u(H, t_f, t_E, t_o; T_C^F, T_C^M, T_C^J, E_H, E_P)$.

It is strictly quasi-concave and at least twice continuously differentiable.

The child divides his own time among food consumption, exercise and other residual activities, so he faces the time constraint:

(3.5) $t_f + t_E + t_o = T$.

T is the total time available to the child which we set at 24 hours per day. The child will maximize his/her own utility, equation (3.4), by making his/her own decisions on the set of choices, (x_f, t_f, t_E, t_o) , while facing two production function constraints (equation (3.2) and equation (3.3)) and the time constraint (equation (3.5)).

The child's maximization problem set up as defined above does not allow parental time spent with the child to enter directly into the child's health production function. The current literature on modeling parental time influence exhibits several ways that the variables can enter the production function directly: parental time allocation can enter the household private and public goods multiple output production function (Apps and Rees 2002); parental time spent with the child can be arguments in a general child quality production function (Hallberg and Klevmarken), and parental time spent with the child also can be variables in the child's effort quality production (Amuwo et al.). In all these cases, the parental time variables, especially the time spent with the child, can have a direct impact on the production outcome. In other words, they are able to influence the general production output level when fixing all other arguments in the production function.

However, the focus of this study is on children's obesity-related health outcomes which are a function of the variables related to the energy intake and energy output balance relationship (Hoffman and Sawaya; Pitt, Rosenzwerg, and Hassan; Park and Davis). When all the energy intake and energy output related variables are fixed, the only way the obesity-related physical health outcome will change is through the person's genetic factor change. Genetics are not influenced by the amount of parental time spent with the child. So, in our modeling, the parental time spent with the child only indirectly influences the child's health outcome production through optimal solutions.

3.1.3. Defining the parent's individual utility function

The parent's individual i's ($i = F, M$) utility function is defined on the following components:

1. A composite market consumption good (X_o^i), with the price set to unity. This is a private consumption good only consumed by the i^{th} individual adult in the household;
2. All the parental time allocation choices: the parental individual time spent with the child (T_C^i), the parental joint time spent with the child (T_C^J), the parental time spent in food preparation (T_f^i), the parental time spent in market work (T_w^i), the other residual parental time (T_o^i);
3. The family and work place influences: the home environment (E_H), and the market work environment (E_w);
4. The child-related factors: the child's own utility outcome (u), and the child's obesity-related health outcome (H).

The parent's individual utility function is then:

$$(3.6) \quad v^i[X_o^i, T_C^i, T_C^J, T_f^i, T_w^i, T_o^i, E_H, E_W, u(\cdot); H],\ i = F, M.$$

Both parent's individual utility functions are strictly quasi-concave and at least twice continuously differentiable.

We allow the parents to have their individual specific preferences. In the Beckerian sense, both of them are "egoistic" toward each other but exhibit the combination of "caring" and "altruistic" toward their child. This means that, among the parents, each parent's own consumption and time allocation choices have no effect on the other. However, they both care about their child's welfare --- the child's utility outcome --- in a way that the child's welfare outcome will bring direct utility to the parents and they do not care how the welfare is achieved except through health outcome. Meanwhile both parents do care enough about the child's obesity-related health outcome that the health outcome will directly bring utility to them. They do not merely want their child to feel "happy" (achieve its maximum utility level). Instead, they want the child to have a certain level of health outcome even though this may bring the child a certain level of disutility.[12]

The parents will face two production function constraints (equation (3.2) and equation (3.3)), a household budget constraint and two individual time constraints. We will discuss these more in the following section.

In our utility function specifications (for the child and for the parents), the time allocation choices not only play roles through constraints but also enter the individual utility functions directly. This allows for joint production in household production. When time becomes an input in the production of a household commodity, the production process exhibits joint production (Becker 1965; Lancaster; Pollak and Wachter). In other words, the household individual members derive utility or disutility not only from the market goods and the household produced commodities, but also from the time they devote to each of the activities (Pollak and Wachter; Hallberg and Klevmarken). Hallberg and Klevmarken call the positive utility brought merely from devoting time to certain activity the "process benefit", which means that the activity will

[12] For example, the child and his parents may have different perceptions about overweight and obesity. The overweight or obese child may not feel any discomfort or he may only feel the peer pressure and self-esteem struggling; the parents may concern about the child's health status and related medical burden. Then the conflict will arise due to this perception gap.

bring certain well-being no matter what the end result is.[13] They find from a time-use survey that, for both male and female, playing with children and being in charge of children gets the highest process benefits scores with the third highest score given to market work.[14]

3.1.4. Defining the parents' objective function and constraints

We have defined the parent's individual utility functions above. Now we need to define a "parents' utility function" in order to analyze the parents-child interaction. That is, we need to define the mechanism that the parents use to make purchasing and time allocation decisions. Follow the collective modeling approaches, we only assume that parents' decision or exchange process will lead to Pareto efficient equilibrium allocation results between parents and it is reasonable in the long-term relationship like household members' interaction (Chiappori 1988; Apps and Rees 1996).

The Pareto efficiency setting requires that, when one parent is maximizing his/her own utility, he/she will make sure that his/her spouse's utility level at least meets a certain reservation utility level $\bar{v}$. This reservation utility level, in general, is a function of the environment (such as individual wage rate and nonwage income) (Chiappori 1992, Apps and Rees 1996). The Lagrangian multiplier of this constraint is, in general, a function of these environmental variables and can be interpreted as the implicit weight of

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[13] For example, the parental time spent with child may not bring immediate positive results to the child's behavior outcome etc. but the parents can derive positive utility from the time they spent with their child because they enjoy being with the child.
[14] It is the Swedish household panel study Household Market and Nonmarket Activities (HUS) time-use surveys (1984-1991).

the spouse's egoistic utility in the collective decision process between the two parents (Chiappori 1992). Browning and Chiappori call it a "distribution of power" function and they point out that it generally depends on the "distribution factors" or the Extra-Environmental Parameters (EEP's) (McElroy) that affect the distribution of "power" within the household, meaning they influence the "distribution of power" function but do not affect the preferences directly.

In our model, we define this "distribution of power" function as *W*. It summarizes the decision process in a way that determines the final location of the optimal solutions on the Pareto frontier. We define it as the function of individual wage rate (w^i) and the individual unearned income (I^i): $W(w^F, w^M, I^F, I^M)$.

Then, we can define the parents' utility function, *v*, as the following:

$$(3.7)\quad v = v^F[X_o^F, T_C^F, T_C^J, T_f^F, T_w^F, T_o^F, E_H, E_W, u(\cdot); H] +$$

$$W(w^F, w^M, I^F, I^M)v^M[X_o^M, T_C^M, T_C^J, T_f^M, T_w^M, T_o^M, E_H, E_W, u(\cdot); H] .$$

By defining the parents' objective function (utility function) this way, we implicitly normalize the father's "distribution of power" to 1. The *W* function here represents the ratio of the mother's power over the father's power. Its value is greater than 0 and can be greater than 1 in the case of the mother having a larger distribution power in the parents decision process.

The parents face two production constraints (equation (3.2) and equation (3.3)) and other constraints.

They face the household budget constraint:

(3.8) $\sum_i (X_o^i + X_f^i) = \sum_i (w^i T_w^i + I^i) \qquad i = F, M$.

We also normalize the price of the food inputs to unity. The LHS of equation (3.8) can be treated as the sum of the expenditures in these two consumption categories. By non-satiation assumption, the inequality sign can be changed into equality. This means that the parents will use up the total income they have to allocate between market good consumption and food input choices.

They also face their individual time constraints:

(3.9) $T_C^F + T_C^J + T_f^F + T_w^F + T_o^F = T$, and

(3.10) $T_C^M + T_C^J + T_f^M + T_w^M + T_o^M = T$.

These two constraints reflect that the parents will devote their time to different activities. They will make their decisions on the set of choices, $(X_f^F, X_f^M, X_o^F, X_o^M, T_C^F, T_C^M, T_C^J, T_f^F, T_f^M, T_w^F, T_w^M, T_o^F, T_o^M)$, to maximize the parents' utility function *V*, equation (3.7), while facing the two production constraints (equation (3.2) and equation (3.3)), the budget constraint (equation (3.8)), and the two individual time constraints (equation (3.9) and equation (3.10)).

3.2. Model Structure

Now that all the variables, utility functions and constraints that go into the model have been defined, the decision structure must be discussed.

3.2.1. Choosing the game structure

The literature on interaction among family members refers to the famous "Rotten Kid Theorem" presented by Becker. Becker (1981) restated his theorem as: "Each beneficiary, no matter how selfish, maximizes the family income of his benefactor and thereby internalizes all effects of his actions on other beneficiaries" (pp. 183). This theorem deals with family members' interaction in a household with a benevolent household head and several family members as beneficiaries. In our study, the parents are acting as a representative benevolent household head while the child is the single beneficiary. So, it is reasonable to follow the model structure the "Rotten Kid Theorem" utilized.

As Bergstrom pointed out, "the Rotten Kid theorem can be described succinctly as a description of equilibrium in a two-stage game" (pp.1145). In the first stage of the game, each beneficiary will choose an "action" which will influence the others' utilities directly; in the second stage of the game, the benevolent household head decides the income distribution among the beneficiaries after observing the "action" choices made by each family member. The Rotten Kid theorem states that the subgame perfect equilibrium for this game is the result the benevolent household head would most prefer if he could choose the "action" sets himself. Our study will use the two-stage game structure for the model derivation.

3.2.2. Choosing the leader

The two-stage game structure is a leader-follower Stackleberg game structure. So the first issue is, between the parents and the child, who will be the leader and who will be the follower in our model.

In the Rotten Kid theorem, the beneficiaries are the leaders who make their action choices first and the benevolent head choose the income distribution after he has observed the action choices. If stated in incentive theory language, following Bergstrom, the Rotten Kid theorem can be stated as: given any action set, *a*, chosen by the *n* agents (the beneficiaries, with utility functions (u_1, u_2,…, u_n)), the utility possibility set, *UP*(*a*), can be achieved if the available income to distribute is *I*(*a*), the income each beneficiary receives is t_i and they satisfied: $\sum_i t_i = I(a)$. The theorem claims that, without the benevolent head committing to any incentive mechanism beforehand, the family members will act as if they are maximizing the household utility instead of maximizing their individual utilities.

However, as Bergstrom points out, if the beneficiaries can act before the household head can commit to an incentive scheme, the Rotten Kid theorem cannot generally hold without any further assumptions. In our study, if the beneficiary (the child) is the leader and the benevolent household head (the parents) is the follower, without any further assumptions (such as transferable utility), the child will choose an inefficient (non-Pareto optimal) choice set (the food choice and time allocation) which he most prefers (his individual utility level is the highest) by distorting the family utility possibility frontier in favor of himself.[15] The child exhibits obvious manipulating power in this case.

Let us examine a simple example which follows arguments similar to those made by Bergstrom. Let a_0 and a_1 be two different actions chosen by the child. The respective resulting household utility possibility frontiers are: $UPF\,(d, a_0) = UPF_0$ and $UPF(d, a_1) = UPF_1$, where d represents the parents' decision choices. The household utility possibility frontiers are achieved by the distribution of the parents' decision choices, given the child's action choice is either a_0 or a_1. Let I_0 and I_1 be parents' (the benevolent household head) indifference curves.

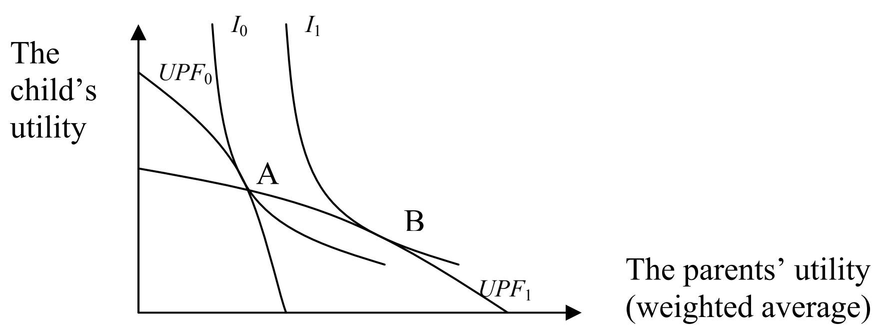

Figure 1: Illustration of Child's Manipulating Power

Figure 1 shows the manipulating power of the child: If the two utility possibility frontiers cross as the way shows in Figure 1, then the child would prefer point A to point

[15] See Bergstrom 1989 paper for more detailed discussion on the transferable utility.

B and parents will prefer point B to point A. So, when the child gets to choose his action first, he will choose the action a_0 over a_1 in order to distort the family utility possibility frontier from UPF_1 to UPF_0. Through this choice, the child can achieve a higher individual utility level but at the expense of the parents.

Because our study explores how parental time allocation can influence the child's obesity-related health outcome, it is more realistic to assume that the parents are the ones who set the family rules (act as the leader) and the child is the follower. This child-parents (the child is the leader) game structure that captures how the child manipulates the parents' decision making does not fit our research purposes.

3.3. Parents-Child Two-Stage Game

This study employs the following two-stage game structure: the parents are the leaders and are able to make decisions over goods consumption, food input purchases and time allocations to achieve Pareto efficient outcomes between themselves, while taking into account of the child's behavior responses to their decisions; the child is the follower and chooses his/her own decision variables for food input and time allocations to maximize his/her own utility function after observing the parents' decision choices.

We assume that the parents know each other's preferences and their interactions result in Pareto efficient outcomes between themselves. As Browning and Chiappori point out, given this symmetric information flow and the repeated "game" nature of the spouses' interaction in the household, it is plausible that the individual parent finds the mechanism to result in efficient outcomes.[16] For parents-child interaction, we also assume that the information flow is symmetric and both sides are fully informed: the child knows his/her parents' preferences and is fully aware that his/her responses to the parental decisions have been considered by the parents;[17] the parents know the child's preference and the ways he/she reacts to their decisions. We do not consider the asymmetric information case, where the child hiding certain behavior from the parents, for two reasons. First, efficient outcomes are naturally the case resulting from long-term interaction in multi-person households, and asymmetric information flow will weaken the efficiency conditions. Second, it will complicate our analysis and distract us from the purpose of this study.

3.3.1. Child's decision making

We follow the backward induction procedure to derive the subgame perfect equilibrium of this two-stage model. Because the child is the follower in this model and makes decisions in the second stage of the game, we start with the child's decision-making process derivation.

As defined in the previous section, the child's problem can be presented as:

$$\underset{(x_f, t_f, t_E, t_o)}{Max}\ u(H, t_f, t_E, t_o; T_C^F, T_C^M, T_C^J, E_H, E_P)$$

[16] Given the perfect information assumption, the long-term equilibrium of a repeated noncooperative game is often the cooperative results.
[17] So the child knows that he/she can act in certain ways to influence the household decision making process.

$$\text{s.t.} \begin{cases} H = H(N, t_E; \mu, k^F, k^M) \\ N = N(x_f, t_f, t_E; X_f^F, X_f^M, T_f^F, T_f^M, E_H, E_P, \mu, k^F, k^M) \\ t_f + t_E + t_o = T \end{cases}$$

The child will choose the set, (x_f, t_f, t_E), to maximize his own utility function while taking the parental choices, $(X_f^F, X_f^M, T_f^F, T_f^M, T_C^F, T_C^M, T_C^J)$, as given. After substituting the constraints back into the utility function, we have the following unconstrained child's utility function:

$$u\{H[N(x_f, t_f, t_E; X_f^F, X_f^M, T_f^F, T_f^M, E_H, E_P, \mu, k^F, k^M), t_E; \mu, k^F, k^M], t_f, t_E, (T - t_f - t_E)$$
$$; T_C^F, T_C^M, T_C^J, E_H, E_P\}.$$

The F.O.Cs of this problem imply the following relationships:

(3.11) $\dfrac{\partial N}{\partial x_f} = 0$

(3.12) $u_H H_N \cdot \dfrac{\partial N}{\partial t_f} + u_{t_f} = u_{t_o}$

(3.13) $u_H (H_N \cdot \dfrac{\partial N}{\partial t_E} + \dfrac{\partial H}{\partial t_E}) + u_{t_E} = u_{t_o}$

From equation (3.12) and equation (3.13), we can have the following relationship:

(3.14) $\underbrace{u_H H_N \cdot \dfrac{\partial N}{\partial t_f}}_{(a)} + \underbrace{u_{t_f}}_{(b)} = u_{t_o} = u_H (\underbrace{H_N \cdot \dfrac{\partial N}{\partial t_E}}_{(c)} + \dfrac{\partial H}{\partial t_E}) + \underbrace{u_{t_E}}_{(d)}$.

This relationship depicts equilibrium conditions for the child's optimal time allocation choices. The left hand side of equation (3.14) is the partial effect of the child's time spent on food consumption and is a combination of two effects. The first term of the left hand side, part (*a*), shows that the child's time spent in food consumption brings indirect utility to the child through nutrient production and the resulting health outcome. The second term of the left hand side, part (*b*), reflects the direct utility/disutility effect the child will derive just from spending time on food consumption. If he/she enjoys eating the food, then it will capture the "process benefit": the positive utility derived from devoting time to enjoying the food consumption, i.e., enjoying the taste and deriving comfort, etc.

The right hand side of equation (3.14) is the partial effect of the child's time spent in exercising and is also a combination of direct and indirect effects. The first term of the right hand side, part (*c*), shows that exercise brings two indirect effects through health outcome production where one indirectly influences the child's health outcome through nutrient intake production and the other directly influence health outcome as energy output. The second term of the right hand side, part (*d*), reflects that exercising time can bring direct utility/disutility to the child depending on whether the child enjoys the exercise or not.

Equation (3.14) captures the equilibrium conditions for the child's time allocation: In equilibrium, all the marginal net benefit from eating food (the left hand side of equation (3.14)), the marginal net benefit from exercising (the right hand side of equation (3.14)) and the marginal cost of loosing other residual time (the middle part of equation (3.14)) must be equal to each other. The child will choose to devote his/her own time to each of these three activity categories to the point where he gets the same marginal utility from all of them.

The F.O.Cs of the child's problem will give us the child's optimal choice set, (x_f^*, t_f^*, t_E^*), which are functions of the given parental choices and the other exogenous variables: $(X_f^F, X_f^M, T_f^F, T_f^M, T_C^F, T_C^M, T_C^J, E_H, E_P, \mu, k^F, k^M)$.[18]

3.3.2. Parents' decision making

Parents act as the leader in this model and they make their resource allocation decisions in the first stage of the game. They are fully informed on how the child will react to the parental decisions they make and will take this into consideration.

As defined in the previous section, the parents' problem can be presented as:

$$\underset{\begin{pmatrix} X_O^F, X_O^M, X_f^F, X_f^M, T_C^F, T_C^M, T_C^J, \\ T_f^F, T_f^M, T_w^F, T_w^M, T_o^F, T_o^M \end{pmatrix}}{Max} \quad v = v^F[X_o^F, T_C^F, T_C^J, T_f^F, T_w^F, T_o^F, E_H, E_W, u^*(\cdot); H^*] +$$

$$W(w^F, w^M, I^F, I^M) \cdot v^M[X_o^M, T_C^M, T_C^J, T_f^M, T_w^M, T_o^M, E_H, E_W, u^*(\cdot); H^*]$$

$$\text{s.t.} \begin{cases} H = H(N^*, t_E^*; \mu, k^F, k^M) \\ N = N(x_f^*, t_f^*, t_E^*, X_f^F, X_f^M, T_f^F, T_f^M, E_H, E_P; \mu, k^F, k^M) \\ \sum_i (X_o^i + X_f^i) = \sum_i (w^i T_w^i + I^i) \qquad i = F, M \\ T_C^F + T_C^J + T_f^F + T_w^F + T_o^F = T \\ T_C^M + T_C^J + T_f^M + T_w^M + T_o^M = T\,. \end{cases}$$

[18] The total time available, T, should be in the optimal solution functions too because it is exogenous to the child's problem also. But because it is constant across individual child (24 hours per day for every child), we leave it out in the variables list.

The parents will make decisions on the choice set,

$(X_f^F, X_f^M, X_o^F, T_C^F, T_C^M, T_C^J, T_f^F, T_f^M, T_w^F, T_w^M)$, to maximize the parents' utility function, v, which is the weighted average of their individual utility functions while taking into account their decision consequences (i.e. the child's response). The variables with an asterisk denote that they are the child's optimal responses to the parents' decisions.

After substituting all the constraints into the parents' utility function, v, the unconstrained problem is:

$$v = v^F\{X_o^F, T_C^F, T_C^J, T_f^F, T_w^F, (T - T_C^F - T_C^J - T_f^F - T_w^F), E_H, E_W, u^*(\cdot);$$

$$H[N(x_f{}^*, t_f{}^*, t_E{}^*, X_f^F, X_f^M, T_f^F, T_f^M, E_H, E_W; \mu, k^F, k^M), t_E{}^*; \mu, k^F, k^M]\}$$

$$\cdot v^M[(\sum_i (w^i T_w^i + I^i - X_f^i) - X_o^F), T_C^M, T_C^J, T_f^M, T_w^M, (T - T_C^M - T_C^J - T_f^M - T_w^M), E_H, E_W, u^*(\cdot);$$

$$H[N(x_f{}^*, t_f{}^*, t_E{}^*, X_f^F, X_f^M, T_f^F, T_f^M, E_H, E_W; \mu, k^F, k^M), t_E{}^*; \mu, k^F, k^M]\}.$$

The F.O.Cs of this unconstrained problem imply the following relationships:[19]

$$\text{(3.15)}\quad \{[v_u^F + W(\cdot)v_u^M]\cdot u_H + [v_H^F + W(\cdot)v_H^M]\}\cdot H_N \frac{\partial N}{\partial X_f^F} + \Delta_{X_f^F} = W(\cdot)v_{X_o^M}^M$$

$$\text{(3.16)}\quad \{[v_u^F + W(\cdot)v_u^M]\cdot u_H + [v_H^F + W(\cdot)v_H^M]\}\cdot H_N \frac{\partial N}{\partial X_f^M} + \Delta_{X_f^M} = W(\cdot)v_{X_o^M}^M$$

$$\text{(3.17)}\quad v_{X_o^F}^F = W(\cdot)v_{X_o^M}^M$$

$$\text{(3.18)}\quad \frac{\partial v^F}{\partial T_C^F} + [v_u^F + W(\cdot)v_u^M]\cdot\frac{\partial u}{\partial T_C^F} + \Delta_{T_C^F} = \frac{\partial v^F}{\partial T_o^F}$$

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[19] The F.O.Cs presented here are the results of utilizing the F.O.Cs results derived from the child's problem.

$$(3.19)\quad W(\cdot)\cdot\frac{\partial v^M}{\partial T_C^M}+[v_u^F+W(\cdot)v_u^M]\cdot\frac{\partial u}{\partial T_C^M}+\Delta_{T_C^M}=W(\cdot)\cdot\frac{\partial v^M}{\partial T_o^M}$$

$$(3.20)\quad \frac{\partial v^F}{\partial T_C^J}+W(\cdot)\cdot\frac{\partial v^M}{\partial T_C^J}+[v_u^F+W(\cdot)v_u^M]\cdot\frac{\partial u}{\partial T_C^J}+\Delta_{T_C^J}=\frac{\partial v^F}{\partial T_o^F}+W(\cdot)\cdot\frac{\partial v^M}{\partial T_o^M}$$

$$(3.21)\quad \frac{\partial v^F}{\partial T_f^F}+\{[v_u^F+W(\cdot)v_u^M]\cdot u_H+[v_H^F+W(\cdot)v_H^M]\}\cdot H_N\frac{\partial N}{\partial T_f^F}+\Delta_{T_f^F}=\frac{\partial v^F}{\partial T_o^F}$$

$$(3.22)\quad W(\cdot)\cdot\frac{\partial v^M}{\partial T_f^M}+\{[v_u^F+W(\cdot)v_u^M]\cdot u_H+[v_H^F+W(\cdot)v_H^M]\}\cdot H_N\frac{\partial N}{\partial T_f^M}+\Delta_{T_f^M}$$

$$=W(\cdot)\cdot\frac{\partial v^M}{\partial T_o^M}$$

$$(3.23)\quad \frac{\partial v^F}{\partial T_w^F}+W(\cdot)\cdot w^F\frac{\partial v^M}{\partial X_o^M}+\Delta_{T_w^F}=\frac{\partial v^F}{\partial T_o^F}$$

$$(3.24)\quad \frac{\partial v^M}{\partial T_w^M}+w^M\frac{\partial v^M}{\partial X_o^M}+\Delta_{T_w^M}=\frac{\partial v^M}{\partial T_o^M}\,.$$

The Δ_i, with $i=(X_f^F,X_f^M,T_C^F,T_C^M,T_C^J,T_f^F,T_f^M,T_w^F,T_w^M)$, is the simplified notation for the following:

$$\Delta_i=[v_H^F+W(\cdot)v_H^M]\frac{dH^*}{di},\ \text{with}\ \frac{dH^*}{di}=H_N(N_{x_f}\frac{\partial x_f^*}{\partial i}+N_{t_f}\frac{\partial t_f^*}{\partial i}+N_{t_E}\frac{\partial t_E^*}{\partial i})+H_{t_E}\frac{\partial t_E^*}{\partial i}\,.$$

All the Δ_i capture how the parents will take their child's responses to the parental decisions into consideration: The child will react to each of the parental decision variables through making adjustments on his/her optimal allocation choices after observing the parental decisions ($\frac{\partial A}{\partial i}$, where $A=(x_f^*,t_f^*,t_E^*)$). Those child's optimal choices' adjustments will, in turn, influence the parent's individual utility function through the child's obesity-related health production outcome ($\frac{dH^*}{di}$). Then, these individual parental utility impacts are weighted according to the "distribution power" function to arrive at the parents' utility impact. The consequence impact through the child's utility is zero because the child will balance out the marginal effects when it is his/her turn to optimize his/her own utility. In other words, the child will reach equilibrium after the parents' decisions. The consequence terms show only the indirect consequence brought about by the child's reaction through the child's health production function.

From equation (3.15) to equation (3.17), we have the following relationship:

$$(3.25)\ \{[v_u^F + W(\cdot)v_u^M]\cdot u_H + [v_H^F + W(\cdot)v_H^M]\}\cdot H_N \frac{\partial N}{\partial X_f^F} + \Delta_{X_f^F}$$

$$= \{[v_u^F + W(\cdot)v_u^M]\cdot u_H + [v_H^F + W(\cdot)v_H^M]\}\cdot H_N \frac{\partial N}{\partial X_f^M} + \Delta_{X_f^M} = v_{X_o^F}^F = W(\cdot)v_{X_o^M}^M$$

Equation (3.25) shows that parents will balance the marginal indirect utility from purchasing food for the child with the marginal direct disutility of loosing their own market good consumption while taking into account the later responses from the child.

Equations (3.18), (3.21), and (3.23) give us the following condition for the father's optimal time allocation choices:

$$(3.26)\ \underbrace{\frac{\partial v^F}{\partial T_C^F} + [v_u^F + W(\cdot)v_u^M]\cdot\frac{\partial u}{\partial T_C^F} + \Delta_{T_C^F}}_{(a)} = \underbrace{\frac{\partial v^F}{\partial T_w^F} + W(\cdot)\cdot w^F\frac{\partial v^M}{\partial X_o^M} + \Delta_{T_w^F}}_{(b)} = \underbrace{\frac{\partial v^F}{\partial T_o^F}}_{(c)}$$

$$= \underbrace{\frac{\partial v^F}{\partial T_f^F} + \{[v_u^F + W(\cdot)v_u^M]\cdot u_H + [v_H^F + W(\cdot)v_H^M]\}\cdot H_N \frac{\partial N}{\partial T_f^F} + \Delta_{T_f^F}}_{(d)}\ .$$

Equation (3.19), (3.22), and (3.24) give us the following condition for the mother's optimal time allocation choices:

$$(3.27)\quad \underbrace{W(\cdot)\cdot\frac{\partial v^M}{\partial T_C^M}+[v_u^F+W(\cdot)v_u^M]\cdot\frac{\partial u}{\partial T_C^M}+\Delta_{T_C^M}}_{(a')}=\underbrace{W(\cdot)\cdot(\frac{\partial v^M}{\partial T_w^M}+w^M\frac{\partial v^M}{\partial X_o^M})+\Delta_{T_w^M}}_{(b')}$$

$$=\underbrace{W(\cdot)\cdot\frac{\partial v^M}{\partial T_o^M}}_{(c')}=\underbrace{W(\cdot)\cdot\frac{\partial v^M}{\partial T_f^M}+\{[v_u^F+W(\cdot)v_u^M]\cdot u_H+[v_H^F+W(\cdot)v_H^M]\}\cdot H_N\frac{\partial N}{\partial T_f^M}+\Delta_{T_f^M}}_{(d')}\cdot$$

Equation (3.26) and (3.27) show that in equilibrium, the father and the mother will devote their individual time to the activities according to the following marginal effect rules. Each of them will make sure that the following marginal effects are equal in the equilibrium:

1. Net marginal utility from spending time with child: a combination of the direct utility, "process benefit", from just enjoying spending time with the child and the indirect utility through the child's utility change;
2. Net marginal utility/disutility from spending time in food preparation: a combination of "process benefit" (or "process bad") just from spending time in preparing food and the indirect utility through the child's health outcome production;
3. Net marginal utility of market work (a combination of direct utility from just enjoying working and indirect utility through the income effect on market goods consumption;
4. The marginal disutility caused by the loss of their individual other residual time.

All of the above marginal effects (except the disutility caused by individual other residual time lost) include consideration of the response consequence caused by the child's reaction.

Now let us take a look at the detailed components of equation (3.26). Part (*a*) of equation (3.26) is the partial impact of the father's time spent with the child on the average weighted parents' utility and has multiple effects. The first term in part (*a*) is the direct utility effect on the average parents' utility through father's individual utility change (the father may merely enjoying spending time with the child) and is weighted by the father's weight which is normalized to 1. The second term in (*a*) is the indirect utility effect on the average parents' utility. It is the weighted average of the father's and mother's individual indirect utility change caused by the marginal effect on the child's utility.

Part (*b*) of equation (3.26) is the partial impact of the father's market working time and has several effects. The first term in part (*b*) is the direct utility effect on the average parents' utility through the father's individual utility change (the father may merely enjoy working). The second term in part (*b*) is the income effect on the mother's market good consumption and is weighted by the "distribution of power" function.

Part (*c*) of equation (3.26) is the direct disutility impact of the father's other residual time lost on the average parents' utility through the father's individual utility change.

Part (*d*) of equation (3.26) is the partial impact of the father's time spent on food preparation and has multiple effects. The first terms in (*d*) are the direct utility/disutility effect on the average parents' utility through the father's individual utility change (the father may or may not enjoy preparing food) and it is weighted by the father's weight which is normalized to 1. The second term in (*d*) is the indirect utility effects on the average parents' utility and is composed of two kinds of indirect effects: first is the weighted average of the father's and mother's individual indirect utility effects through the child's utility change caused by the nutrient production influence of T_f^F ; second is the weighted average of the father's and mother's individual indirect utility effects through the child's health outcome change (which directly enters both parents' individual utilities) caused by the nutrient production influence of T_f^F .

Equation (3.27) is similar to equation (3.26) and its components show the equilibrium conditions for the mother's time allocation choices. The individual parts (*a'*) to (*d'*) have similar meanings to parts (*a*) to (*d*) with the only difference being that the direct utility impact on the average parents' utility is through the mother's individual utility change instead of the father's and it is weighted by the "distribution of power" function, $W(\cdot)$.

Equation (3.20) is the optimal condition for allocating the parental joint time spent with child. It shows that the parents will make a joint decision on the joint time spent with their child by balancing the weighted average benefit (direct "process benefit" and the indirect utility through child's utility change) with the weighted average cost of losing their individual other residual time.

The F.O.Cs of the parents' problem will give the optimal solutions for $(X_f^{F^*}, X_f^{M^*}, X_o^{F^*}, T_C^{F^*}, T_C^{M^*}, T_C^{J^*}, T_f^{F^*}, T_f^{M^*}, T_w^{F^*}, T_w^{M^*})$ as functions of $(w^F, w^M, I^F, I^M, E_H, E_P, E_W, \mu, k^F, k^M)$.

3.4. Parental Time's Partial Effect

Based on the model derived in the previous section, we can explore parental time's expected partial effect.

3.4.1. The comparative statics results

As we have derived in the child's maximization problem, the child's optimal choices, $(x_f{}^*, t_f{}^*, t_E{}^*)$, are functions of the given parental choices and the other exogenous variables: $(X_f^F, X_f^M, T_f^F, T_f^M, T_C^F, T_C^M, T_C^J, E_H, E_P, \mu, k^F, k^M)$. Substituting these optimal solutions into the child's nutrient intake production function and the child's obesity-related health outcome production function, we have: $H = H^*(N^*, t_E^*; \mu, k^F, k^M)$.

It is clear that the effect of parental time spent with the child, T_C^i (with $i = F, M, J$), on the child's obesity-related health outcome, H, combines several effects:

(3.28) $$\frac{\partial H^*}{\partial T_C^i} = \frac{\partial H}{\partial N}\frac{\partial N^*}{\partial T_C^i} + \frac{\partial H}{\partial t_E}\frac{\partial t_E{}^*}{\partial T_C^i} = H_N \frac{\partial N^*}{\partial T_C^i} + H_{t_E}\frac{\partial t_E{}^*}{\partial T_C^i},\ i = F, M, J.$$

The parental time partial effect on the child's health outcome is a combination of two effects: the indirect marginal effect through nutrient production change (energy intake effect) and the indirect marginal effect through exercising time change (energy output effect). After looking at each component, it is not a straight-forward process to sign the parental partial effect, $\frac{\partial H^*}{\partial T_C^i}$, without further assumptions.

Let us look at the Primal-Dual (P-D) signing equation from our theoretical model to see what kind of sign our theory suggests for this parental partial effect, $\frac{\partial H^*}{\partial T_C^i}$ (Silberberg and Suen, Chapter 7). The comparative statics signing equation for $\frac{\partial H^*}{\partial T_C^i}$ is:[20]

$$u_{T_C^i H}(H_N \cdot \frac{\partial N^*}{\partial T_C^i} + H_{t_E} \cdot \frac{\partial t_E^*}{\partial T_C^i}) + (u_{T_C^i t_E} - u_{T_C^i t_o}) \cdot \frac{\partial t_E^*}{\partial T_C^i} + (u_{T_C^i t_f} - u_{T_C^i t_o}) \cdot \frac{\partial t_f^*}{\partial T_C^i} \geq 0 .$$

By equation (3.28), the above inequality can be rewritten as:

$$(3.29) \quad u_{T_C^i H} \cdot \frac{\partial H^*}{\partial T_C^i} + (u_{T_C^i t_E} - u_{T_C^i t_o}) \cdot \frac{\partial t_E^*}{\partial T_C^i} + (u_{T_C^i t_f} - u_{T_C^i t_o}) \cdot \frac{\partial t_f^*}{\partial T_C^i} \geq 0 .$$

After substituting all the constraints into the child's utility function, the child's utility maximization problem becomes an unconstrained optimization problem. So the P-D relationship is the same as the unconstrained one.

Although the inequality (3.29) does not have constraints or Lagrangian multipliers in it, we still can not sign the partial parental time effect on the child's health outcome, $\frac{\partial H^*}{\partial T_C^i}$. Since the signed inequality (3.29) is still the summation of three separate effects, it is hard to untangle without further assumptions. The other two terms in the LHS of the

[20] Detailed derivation is available from the author upon request.

inequality (3.29) can not be cancelled out because of the generality nature of our model structure: parental time spent with the child, T_C^i (with $i = F, M, J$), enters more than one first-order condition. As *conjugate pairs theorem* states, "refutable comparative statics theorem will be forthcoming in a maximization model only if a given parameter enters one and only one first-order equation." (Silberberg and Suen, pp.120-121).[21]

3.4.2. The assumptions needed for signing

The left hand side of inequality (3.29) is composed of three different effects of parental time spent with the child. The first term is the effect on the child's optimal health outcome, the second term is the effect on the child's optimal exercising time allocation and the third term is the effect on the child's food consumption time allocation. In order to sign the parental time partial effect on the child's optimal health outcome, we need to know the signs and magnitudes of the other two partial effects, ($\frac{\partial t_E^*}{\partial T_C^i}, \frac{\partial t_f^*}{\partial T_C^i}$), and we also need to make assumptions on all the cross effects on the child's utility level. Several sign combinations exist.

Let us see a few examples to illustrate the kind of assumptions needed in order to determine the sign of the partial parental time effect.

First, let us assume that if the father is able to spend more time with the child, the child will spend more time exercising and consuming food. We then have:

[21] It is for the case of unconstrained optimization problem.

$\frac{\partial t_E^*}{\partial T_C^F} > 0, \frac{\partial t_f^*}{\partial T_C^F} > 0$. Also, when a health-conscious father spends more time with the child, the child is more likely to develop healthy eating habits and have more health consciousness. Then the child's own health outcome can bring relatively more positive marginal utility to the child. This gives us: $u_{T_C^F H} > 0$. Furthermore, if we assume that the child's marginal utilities, derived from his/her time allocation over the activities, will be increased with the time his/her father spends with him/her, we have: $u_{T_C^F t_E} > 0, u_{T_C^F t_f} > 0, u_{T_C^F t_o} > 0$. With all these assumptions, we can have the following inequality:

$$\underset{(+)}{u_{T_C^F H}} \cdot \frac{\partial H^*}{\partial T_C^F} + (\underset{(+)}{u_{T_C^F t_E}} - \underset{(+)}{u_{T_C^F t_o}}) \cdot \underset{(+)}{\frac{\partial t_E^*}{\partial T_C^F}} + (\underset{(+)}{u_{T_C^F t_f}} - \underset{(+)}{u_{T_C^F t_o}}) \cdot \underset{(+)}{\frac{\partial t_f^*}{\partial T_C^F}} \geq 0 .$$

However, we still cannot sign the partial parental effect, $\frac{\partial H^*}{\partial T_C^F}$: it can be positive or negative without any magnitude assumptions. Now, if we are willing to assume that the magnitudes of the cross effects follow a certain order: $u_{T_C^F t_o} > u_{T_C^F t_E}, u_{T_C^F t_o} > u_{T_C^F t_f}$. This means that we assume the father's time spent with the child will bring more marginal effect increases to the child's other residual time compared to food consumption and exercising time. Then we have the following inequality:

$$\underset{(+)}{u_{T_C^F H}} \cdot \frac{\partial H^*}{\partial T_C^F} + \underset{(-)}{(u_{T_C^F t_E} - u_{T_C^F t_o})} \cdot \underset{(+)}{\frac{\partial t_E^*}{\partial T_C^F}} + \underset{(-)}{(u_{T_C^F t_f} - u_{T_C^F t_o})} \cdot \underset{(+)}{\frac{\partial t_f^*}{\partial T_C^F}} \geq 0 .$$

We can then expect that the partial father time effect on the child's obesity-related health outcome, $\frac{\partial H^*}{\partial T_C^F}$, will have the same sign as the cross effect ,$u_{T_C^F H}$, which is positive if the father is health conscious. Therefore, based on all the assumptions stated above, if the father makes a positive impact on the child's perception of his own health by spending time with the child, then the more time the father spends with his child, the healthier his child will be.

If we are willing to assume that the father's time spent with the child has almost no impact on the child's marginal utility of different time allocations (which may be a possible case with teenagers), then we can expect that $\frac{\partial H^*}{\partial T_C^F}$ will have the same sign as $u_{T_C^F H}$, because all the cross effects are zero by the assumption: $u_{T_C^F t_E} = u_{T_C^F t_f} = u_{T_C^F t_o} = 0$.

The inequality (3.29) becomes: $u_{T_C^F H} \cdot \frac{\partial H^*}{\partial T_C^F} \geq 0$.

If we assume that a father who is concerned about his child's obesity-related health outcome (maybe the child is an overweight child) will spend time trying to influence the child to exercise more (be more active) and eat fewer snacks (decrease total food consumption), etc., then inequality (3.29) becomes the following based on the same cross effects assumptions made before:

$$\underset{(+)}{u_{T_C^F H}} \cdot \frac{\partial H^*}{\partial T_C^F} + (\underset{(+)}{u_{T_C^F t_E}} - \underset{(+)}{u_{T_C^F t_o}}) \cdot \underset{(+)}{\frac{\partial t_E^*}{\partial T_C^F}} + (\underset{(+)}{u_{T_C^F t_f}} - \underset{(+)}{u_{T_C^F t_o}}) \cdot \underset{(-)}{\frac{\partial t_f^*}{\partial T_C^F}} \geq 0 .$$

In this case, if the cross effects have the magnitudes following of $u_{T_C^F t_f} > u_{T_C^F t_o} > u_{T_C^F t_E}$,

we assume that the father's time spent with the child may bring greater increase in the marginal utility to food consumption time and less increase to the marginal utility of exercising time. Under these assumptions, the inequality can be rewritten as:

$$\underset{(+)}{u_{T_C^F H}} \cdot \frac{\partial H^*}{\partial T_C^F} + \underset{(-)}{(u_{T_C^F t_E} - u_{T_C^F t_o})} \cdot \underset{(+)}{\frac{\partial t_E^*}{\partial T_C^F}} + \underset{(+)}{(u_{T_C^F t_f} - u_{T_C^F t_o})} \cdot \underset{(-)}{\frac{\partial t_f^*}{\partial T_C^F}} \geq 0 .$$

Then $\frac{\partial H^*}{\partial T_C^F}$ will have the same sign as the cross effect, $u_{T_C^F H}$.

Thus, our theoretical model suggested that, without further assumptions, it is impossible to sign the partial parental effects on the child's obesity-related health outcomes.

3.4.3. The "distribution of power" function

In the parents' maximization problem illustrated in the previous sections, we can see that the "distribution of power" function, $W(w^F, w^M, I^F, I^M)$, appears in all first-order conditions. It is interesting to explore how $W(w^F, w^M, I^F, I^M)$ affects the parents' decision making process.

Take part (*a*) and (*c*) in equation (3.23) as an example:

(3.30) [22] $$\{\underset{(a)}{\frac{\partial v^F}{\partial T_C^F}} + \underset{(b)}{[v_u^F + W(\cdot)v_u^M]} \cdot \underset{(c)}{\frac{\partial u}{\partial T_C^F}}\} + \underset{(d)}{[v_H^F + W(\cdot)v_H^M]}\underset{(e)}{\frac{dH^*}{dT_C^F}} = \frac{\partial v^F}{\partial T_o^F}.$$

If this equilibrium condition results in a certain level of the father's time spent with the child, $T_C^{F^*}$, and if the mother's utility weight within the household increases (maybe due to government policy or market wage rate increases for the mother), then the total value of part (*b*) and part (*d*) in equation (3.30) will increase and will result in the following inequality:[23]

(3.31) $$\{\underset{(a)}{\frac{\partial v^F}{\partial T_C^F}} + \underset{(b)}{[v_u^F + W(\cdot)v_u^M]} \cdot \underset{(c)}{\frac{\partial u}{\partial T_C^F}}\} + \underset{(d)}{[v_H^F + W(\cdot)v_H^M]}\underset{(e)}{\frac{dH^*}{dT_C^F}} > \frac{\partial v^F}{\partial T_l^F}.$$

In order to come back to equilibrium, the father will reallocate his time devotion choices. By the decreasing marginal utility assumptions, we have:

$$\frac{\partial^2 v^F}{\partial T_C^F \partial T_C^F} < 0, \frac{\partial^2 u}{\partial T_C^F \partial T_C^F} < 0.$$

To decrease the total value of the left hand side of inequality (3.31), the father should increase his time spent with the child from $T_C^{F^*}$ to $T_C^{F^{**}}$ ($T_C^{F^{**}} > T_C^{F^*}$). This will then simultaneously decrease the total value of the terms inside of the brackets on the left hand side by the decreasing marginal utility assumptions.

However, the impact on the last term, part (*e*), of the left hand side of inequality (3.31), still requires more assumptions. If more of the father's time spent with the child

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[22] It is the result after substituting the $\Delta_{T_C^F}$ into the equation.

[23] Mother's utility weight increase means that the "distribution of powers", $W(\cdot)$, increases. It is the ratio of mother's utility weight over father's utility weight.

brings decreasing marginal health consequence effects, $\frac{d^2 H^*}{dT_C^F dT_C^F} < 0$, then increasing T_C^F will bring a total of three decreasing effects to the left hand side of inequality (3.31) (part (*a*), (*c*) and (*d*)) until the inequality reaches equilibrium again.

This example shows how the parents' "distribution of power" function, *W*, can influence the parents' time allocation decision choices.

3.5. Chapter Summary

In this chapter, we lay out the theoretical foundation for our analysis. A household with two parents and one child is modeled. We combine the household production theory and the collective household modeling structure to capture the dynamics taking place in this multi-person household. Because the focus of our study is on the impact of parental time allocation choices on the child's obesity-related health outcomes, household production is limited to the child's obesity-related health production. The nutrition literature helps us to define two household production functions which generate a nested health production constraint for the model.

The two parents and one child all have their own specific preferences and the child is allowed to have his own decision choices. The interaction between the parents and the child is modeled as a two-stage Stackleberg game. The parents act as the leader by setting up the family rules and making parental decisions first while taking into account the child's possible responses to their decisions. The child is the follower who makes his own decisions after observing the parental choices made in the first stage. This game structure allows us to explore parental influence on the child's health outcome while allowing the child to have some say so in the household decision making process.

Based on the theoretical model presented in this chapter, an empirical model is derived and will be presented in the following chapter. The theory helps us to specify the empirical model and the data in a theoretically consistent way.

CHAPTER IV

EMPIRICAL MODEL AND ESTIMATION STRATEGIES

In the previous chapter, a Stackleberg game structure is developed for a household with two parents and one child. Each has his/her own specific preferences and the child is able to influence the family decision-making process by having his/her own choices. This leader-follower game structure leads to an empirical health production function for the child's obesity-related health outcome.

4.1. Empirical Health Production Function

4.1.1. The two specifications for the health production function

The Stackleberg game presented in the theoretical chapter has the following stage structure:

1. Stage 1: The two parents are acting as the Stackleberg leader and they maximize their collective utility function for any given decision choice of the child. In other words, the parents make their decision choices while considering the response consequences from the child;
2. Stage 2: The child observes the parental decisions, then the child makes his/her own choices. Because of no uncertainty in this game, the child's decisions take into account the parental choices.

This specific stage structure leads to two specifications for the child's obesity-related health production function, *H*.

In the second stage of the game, the child (the Stackleberg follower) makes decisions on his/her own food choice and time allocations taking the parental decisions as exogenous.[24] The optimal choice set is (x_f^*, t_f^*, t_E^*). So the child's optimal choices are functions of the parental decisions and the other exogenous variables:[25] $(X_f^F, X_f^M, T_f^F, T_f^M, T_C^F, T_C^M, T_C^J, E_H, E_P, \mu, k^F, k^M)$. So in this stage of the game, the child's obesity-related health production function is:

$$(4.1) \quad H = H^*(N^*, t_E^*; \mu, k^F, k^M)$$

$$= H(X_f^F, X_f^M, T_f^F, T_f^M, T_C^F, T_C^M, T_C^J, E_H, E_P, \mu, k^F, k^M).$$ [26]

In the first stage of the game, the parents (the Stackleberg leader) make their decisions based on their own market goods consumption, food choices and their time allocations based on the "distribution of power" in order to achieve Pareto efficient resource allocation between them. Their optimal choice set is $(X_f^{F^*}, X_f^{M^*}, X_o^{F^*}, T_C^{F^*}, T_C^{M^*}, T_C^{J^*}, T_f^{F^*}, T_f^{M^*}, T_w^{F^*}, T_w^{M^*})$. Because they are able to act before the child, the parents can form their best responses to any given set of the child's optimal decisions. So the parents' optimal choices are functions of the exogenous variables: $(w^F, w^M, I^F, I^M, E_H, E_P, E_W, \mu, k^F, k^M)$. In this stage of the game, the child's obesity-related health production function is:

$$(4.2) \quad H = H^{**}(N^{**}, t_E^{**}; \mu, k^F, k^M)$$

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[24] This is because of the no uncertainty assumption.

[25] The child's optimal choices are functions of those parental decisions that enter into the child's health production function indirectly through nutrition production function and those enter the child's utility function directly.

[26] The double asterisks denote that these are the results after substituting the parental optimal decisions back into the child's optimal choices.

$$= H(w^F, w^M, I^F, I^M, E_H, E_P, E_W, \mu, k^F, k^M) .$$

4.1.2. Choosing the specification for the empirical estimation

The two equations above (equation (4.1) and equation (4.2)) are specifications for the child's obesity-related health production function. Equation (4.2) is the reduced form equation derived from this two-stage game because its right hand side arguments are all the exogenous variables that are predetermined in both stages of the game. However, it does not provide us with the information needed to explore how the parental decision variables influence the child's obesity-related health outcome. Because equation (4.2) does not have the parental decision variables as its arguments, it is hard to disentangle the partial effects of the parental decisions on the child's health outcome.

Equation (4.1) is a reduced form equation from the child's point of view (a reduced form derived in the second stage of the game). The right hand side variables of equation (4.1) are the parental decision variables and other exogenous variables. Because the child is the second mover, the parental decisions (the first mover's actions) are given to the child. So from the child's point of view, all the right hand side arguments of equation (4.1) are predetermined, which defines a reduced form equation.

Meanwhile, equation (4.1) is qualified as a structural equation from the parents' point of view (a structural equation illustrating the relationship between variables based on the theory in the first stage of the game). It serves as the starting point of the parents' optimization problem.

As Rosenzweig and Schultz point out, the reduced form health equation (e.g., equation (4.2)) does not provide information on underlying household health technology. They also mention that the reduced form input demand functions possess identical properties to those derived from models without any household production embodied.[27] Equation (4.1), a structural equation in the parents' stage of the game, preserves the relationship between parental choices and the child's obesity-related health outcome, which is the focus of our study. So we choose to use equation (4.1) as the function to be specified for empirically estimating the child's obesity-related health production function and exploring the partial effects of parental decisions.

4.2. Empirical Model

4.2.1. Single equation or a system

Estimating equation (4.1) alone without recognizing the endogeneity problem will bring about biased estimates. Rosenzweig and Schultz point out that, for the general health production problem, the health technology estimation should take into account health inputs' self-selection issues. The OLS estimates of equation (4.1) will be contaminated by heterogeneity bias due to self-selected health inputs (those parental choice variables). They also suggest that this type of estimation must be obtained from a behavioral model that treats health inputs as choice variables, which we have done in the previous theoretical chapter.

[27] For example, the optimal solution functions for those parental decision variables that enter the health production function are actually reduced form health input demand functions.

In our case, the parental choice variables that enter the right hand side of equation (4.1) may bring correlations between health inputs and the health outcome. The theoretical model presented in the previous chapter provides a behavior model that treats those health inputs as parents' own choices. As discussed in the above section, equation (4.1) is a structural equation from the parents' point of view. In the parents' stage of the game, the parental decision variables have the optimal solutions, $(X_f^{F^*}, X_f^{M^*}, X_o^{F^*}, T_C^{F^*}, T_C^{M^*}, T_C^{J^*}, T_f^{F^*}, T_f^{M^*}, T_w^{F^*}, T_w^{M^*})$, and they are functions of all the exogenous variables, $(w^F, w^M, I^F, I^M, E_H, E_P, E_W, \mu, k^F, k^M)$. So there are also several reduced form equations in this stage of the games (the optimal parental choices equations) that are reduced form health input demands.

We can estimate equation (4.1) by utilizing the arguments in those reduced form optimal parental choice functions as instruments. In the first stage, the parental choice functions are estimated for those parental decision variables that are in the right hand side of equation (4.1). Then the estimated parental choices are employed in a second stage to estimate the child's obesity-related health production function (equation (4.1)). This two-stage least squares (2SLS) estimation will provide us consistent estimators.

However, the 2SLS estimation, although achieving consistency, is not efficient in the sense that it ignores the reduced-form restrictions implied by the theoretical model (Court; Rosenzweig and Schultz). A potential and achievable efficiency can be gained if we put the structural equations of interest together with any number of reduced form equations and estimate all of them jointly as a system (Court; Rosenzweig and Schultz).

We can estimate a system by putting the child's obesity-related health production function (equation (4.1), the structural equation of interest) together with the reduced form parental optimal choice equations and estimate them simultaneously in order to achieve both consistency and efficiency. According to the specific structure of this system, it is qualified as a general triangular system and will be discussed further in section 4.3.2. Also, available data points and the degree of freedom problem are common among cross-sectional data sets, and is the case with our collected data set as well.[28] By estimating an empirical system instead of a single empirical equation, we also gain the degree of freedom by increasing the number of available data points. For example, if a data set has *n* available data points and an empirical system utilizing this data set includes *m* equations, then the total number of observations available for this empirical system estimation should be equal to $n * m$.

4.2.2. Empirical system modification due to data limitation

If an empirical system is constructed as discussed above, the system will be:

(4.3a) $X_f^F = X_f^F(w^F, w^M, I^F, I^M, E_H, E_P, E_W, \mu, k^F, k^M)$

(4.3b) $X_f^M = X_f^M(w^F, w^M, I^F, I^M, E_H, E_P, E_W, \mu, k^F, k^M)$

(4.3c) $T_f^F = T_f^F(w^F, w^M, I^F, I^M, E_H, E_P, E_W, \mu, k^F, k^M)$

(4.3d) $T_f^M = T_f^M(w^F, w^M, I^F, I^M, E_H, E_P, E_W, \mu, k^F, k^M)$

(4.3e) $T_C^F = T_C^F(w^F, w^M, I^F, I^M, E_H, E_P, E_W, \mu, k^F, k^M)$

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[28] Details will be discussed in the later chapters.

$$(4.3f)\, T_C^M = T_C^M(w^F, w^M, I^F, I^M, E_H, E_P, E_W, \mu, k^F, k^M)$$

$$(4.3g)\, T_C^J = T_C^J(w^F, w^M, I^F, I^M, E_H, E_P, E_W, \mu, k^F, k^M)$$

$$(4.1)\ H = H(X_f^F, X_f^M, T_f^F, T_f^M, T_C^F, T_C^M, T_C^J, E_H, E_P, \mu, k^F, k^M).$$

Equation (4.3a) to equation (4.3g) are the reduced form health input demand equations and equation (4.1) is the structural health production equation of interest.

However, before discussing the identification issue of this empirical system, we need to verify that the data needs of this empirical system match our collected household survey data set.[29]

First, in the survey data we collected, both parents were asked to provide information on the household's expenditure patterns. They were not only asked about the monthly expenditures in a variety of different categories, but also who is in charge of making the monthly expenditure in each of the expenditure categories. Among those expenditure categories, there are three categories qualified as the household's expenditure on food. However, the data set does not provide information on the parent's individual expenditure choices. So the parent's individual food expenditure choices, (X_f^F, X_f^M), must be modified to accommodate this data limitation. In our empirical system, they will be replaced with the household's food expenditure, X_f.[30] As a result, only the partial effect of the household's food expenditure can be analyzed and the two

[29] The data collection details and the data contents and properties will be discussed in the following chapters.
[30] Detailed generation process will be discussed in the following chapters.

reduced form demand functions for (X_f^F, X_f^M) are summed together to get the reduced form demand function for X_f.

Second, the data set we collected has detailed time use data. Both parents were asked to individually keep track of all of their activities during a 48-hour period using a designed time diary form. The details will be discussed in the following chapters. The time diary data we collected has a high response rate. In our sample, there were only four fathers and eight mothers who completed only one day of the time diary, all others provided complete two-day records. However, we still do not have satisfactory information required to identify the parents' joint time spent with the child. Although the parents were asked to provide the information on who is with them during a given activity, the response rate on this specific information is low and of low quality. Including parental joint time with the child variable will further decrease the available data points. So in the empirical system, the parental time with the child, (T_C^F, T_C^M), includes the parental joint time spent with the child, T_C^J.

Third, in the survey, both parents were asked to provide information about their sources of earned income such as wages, salaries, commissions, etc., and their work schedule as well as sources of unearned income such as investment incomes, rental income, interest, etc. However, these income source data do not meet our data needs for the empirical system. The earned income sources the parents provided are monthly, while the working hours provided are weekly amounts which corresponds only to the week previous to the survey period. Among the parents surveyed, there are part-time employees who may be on and off work during that year. So, in the empirical system, we assume that the time allocated to work, (T_w^F, T_w^M), has been predetermined and remains constant in the short run (Amuwo et al.). This can be a reasonable assumption for cross-sectional data which covers a short period of time.

Based on the above modifications, the budget constraint for the parents will change from equation (3.8) to:

(4.4) $\sum_i X_o^i + X_f = \sum_i Y^i \qquad i = F, M$,

where Y^i is the individual parent's total income (the individual earned income plus the individual unearned income). The two parental time constraints will change from equation (3.9) and (3.10) to:

(4.5) $T_C^F + T_f^F + T_o^F = T - T_w^F = T^F$,

(4.6) $T_C^M + T_f^M + T_o^M = T - T_w^M = T^M$,

where T^i, $i = F, M$, is the non-work time available to the individual parent and the residual time left after devoting time to market work. Parental time spent with the child, (T_C^F, T_C^M), now includes their individual time spent with the child and the joint time spent with the child.

The modified empirical system allowing for data limitations becomes:

(4.7a) $X_f = X_f(Y^F, Y^M, E_H, E_P, E_W, \mu, k^F, k^M, T^F, T^M)$

(4.7b) $T_f^F = T_f^F(Y^F, Y^M, E_H, E_P, E_W, \mu, k^F, k^M, T^F, T^M)$

(4.7c) $T_f^M = T_f^M(Y^F, Y^M, E_H, E_P, E_W, \mu, k^F, k^M, T^F, T^M)$

(4.7d) $T_C^F = T_C^F(Y^F, Y^M, E_H, E_P, E_W, \mu, k^F, k^M, T^F, T^M)$

(4.7e) $T_C^M = T_C^M(Y^F, Y^M, E_H, E_P, E_W, \mu, k^F, k^M, T^F, T^M)$

(4.1’) $H = H(X_f, T_f^F, T_f^M, T_C^F, T_C^M, E_H, E_P, \mu, k^F, k^M)$.

4.3. Identification and Estimation Strategies

4.3.1. Simple linear specification and identification

For simplicity, we start with a simple linear function specification for the above empirical system. This linear specification of the system is:

(4.7a’) $$X_f = a_{10} + a_{11}Y^F + a_{12}Y^M + a_{13}E_H + a_{14}E_P + a_{15}E_W + a_{16}\mu + a_{17}k^F + a_{18}k^M + a_{19}T^F + a_{110}T^M + \varepsilon_1$$

(4.7b’) $$T_f^F = a_{20} + a_{21}Y^F + a_{22}Y^M + a_{23}E_H + a_{24}E_P + a_{25}E_W + a_{26}\mu + a_{27}k^F + a_{28}k^M + a_{29}T^F + a_{210}T^M + \varepsilon_2$$

(4.7c’) $$T_f^M = a_{30} + a_{31}Y^F + a_{32}Y^M + a_{33}E_H + a_{34}E_P + a_{35}E_W + a_{36}\mu + a_{37}k^F + a_{38}k^M + a_{39}T^F + a_{310}T^M + \varepsilon_3$$

(4.7d’) $$T_C^F = a_{40} + a_{41}Y^F + a_{42}Y^M + a_{43}E_H + a_{44}E_P + a_{45}E_W + a_{46}\mu + a_{47}k^F + a_{48}k^M + a_{49}T^F + a_{410}T^M + \varepsilon_4$$

$$(4.7e')\ T_C^M = a_{50} + a_{51}Y^F + a_{52}Y^M + a_{53}E_H + a_{54}E_P + a_{55}E_W + a_{56}\mu + a_{57}k^F + a_{58}k^M + a_{59}T^F + a_{510}T^M + \varepsilon_5$$

$$(4.1'')\ H = b_1 + b_2X_f + b_3T_f^F + b_4T_f^M + b_5T_C^F + b_6T_C^M + b_7E_H + b_8E_P + b_9\mu + b_{10}k^F + b_{11}k^M + \varepsilon_6 .$$

As shown above, this empirical system consists of six equations with five reduced form equations (equation (4.7a') to equation (4.7e')) and one structural equation (equation (4.1'')). Equation (4.7a') to equation (4.7e') are already identified by their reduced form properties. The identification issue of this empirical system now rests on the identification of equation (4.1'').

The order condition for identification of an equation *j* is stated as: "The number of exogenous variables excluded from equation *j* must be at least as large as the number of endogenous variables included in equation *j*" (Greene, pp.392). As Greene points out, in general, a model that passes the order condition will meet the rank condition also. So here we only check the order condition.

The exogenous variables that are excluded from equation (4.1'') are, $(Y^F, Y^M, T^F, T^M, E_W)$. So the number of the exogenous variables that are excluded from equation (4.1') is five. The endogenous variables that are in equation (4.1'') are, $(X_f, T_f^F, T_f^M, T_C^F, T_C^M)$, which gives us five included endogenous variables. This means that equation (4.1'') is exactly identified if all the variables are scalars. There is only one variable among them has the possibility of being defined as a vector in the later data specification. This variable is the work environment variable, E_W, which may include the work flexibility variable and the work commitment variable. The details will be discussed in the data specification chapter. If the work environment is a vector, equation (4.1’’) is then over-identified.

4.3.2. Triangular system and estimation strategies

The empirical system presented in the above section consists of six equations. The last equation, equation (4.1’’), contains the other five equations’ endogenous variables and those five equations do not have any endogenous variables as their right hand side arguments. If we organize the system by putting the endogenous variables all to the left hand side of the equations, the system can be presented in the following matrix form:

(4.8) $BY = CX + U$.

Y is a vector of all the endogenous variables: $Y' = [X_f, T_f^F, T_f^M, T_C^F, T_C^M, H]$. Its associated coefficient matrix B is of the form:

$$B = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & -b_2 \\ 0 & 1 & 0 & 0 & 0 & -b_3 \\ 0 & 0 & 1 & 0 & 0 & -b_4 \\ 0 & 0 & 0 & 1 & 0 & -b_5 \\ 0 & 0 & 0 & 0 & 1 & -b_6 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}.$$

It is clear that the coefficient matrix B is a special case of an upper triangular matrix. So this empirical system is called the triangular system (Greene; Kmenta). X is an 11×1 vector of all the exogenous variables plus one for the intercept term:

$X' = [1, Y^F, Y^M, E_H, E_P, E_W, \mu, k^F, k^M, T^F, T^M]$ and its associated coefficient matrix C is a 6×11 matrix. The disturbance vector U is of dimension: 6×1.

Denote the covariance matrix of the disturbance, U, to be:

$$E(UU'|X) = \Sigma .$$

If the disturbances in the system are uncorrelated, Σ is diagonal, and the system is a fully recursive system (Greene, pp. 397). This recursive system is a special case of the triangular system. It is well known that the ordinary least square (OLS) estimates are consistent for the fully recursive system. This means that if the empirical system is a fully recursive system, we can consistently estimate the system using equation-by-equation OLS.

However, it is clear that the disturbance term in the structural health outcome equation (equation (4.1')) may be correlated with the other five disturbances through the endogenous variables that are in the right hand side of equation (4.1'). So our empirical system is a general triangular system with non-diagonal disturbance covariance matrix, Σ. Generally, OLS estimates bring about a simultaneous equation bias which can be corrected by using three-stage least square (3SLS).

Lahiri and Schmidt suggest that the general triangular system can be estimated consistently and efficiently using the seemingly unrelated regressions (SUR) method. Meanwhile, they point out that only if the covariance matrix, Σ, is known, will efficiency be gained simply by using SUR method. Since it is almost never the case in practice that the covariance matrix, Σ, is known, using SUR is not recommended.

Lahiri and Schmidt suggest using the iterated SUR to achieve the algebraically same results as the full information maximum likelihood (FIML) estimator. However as Prucha points out, the covariance matrix from the iterated SUR is not consistent. A consistent estimator of the covariance matrix can be obtained by using the parameter estimates from the iterated SUR as starting values for a FIML routine and taking the standard errors from the routine.

It is well known that when the covariance matrix, Σ, is unknown, the FIML and 3SLS are equally efficient. We choose to use the iterated 3SLS (IT3SLS) as the procedure for our triangular system estimation. However, as is common in cross-sectional analysis, the instruments we have may be weak. As Park and Davis show, when instruments are weak, the instrumental variable (IV) estimators exhibit poor and misleading asymptotic properties. In our empirical estimation, both the iterated seeming unrelated regression (ITSUR) and IT3SLS results will be presented and the robustness across both estimators will be examined. We use ITSUR to compare with IT3SLS instead of individual OLS results because we have developed the triangular system from our theoretical framework which minimizes the potential equation misspecification. By utilizing the theory-based empirical system running ITSUR instead of OLS, we will be able to gain efficiency without contaminating the whole system with misspecification.

4.4. Chapter Summary

According to the theoretical model presented in the previous chapter, two specifications are derived for the child's obesity-related health production function. The specification with parental decision variables as its arguments is selected as our empirical specification. The specific stage of the theoretical game structure also provides us with several reduced form health input demand functions. The child's health production function is combined with the reduced form demand functions (the parental choice equations) to construct an empirical system in order to gain consistency and efficiency.

This constructed empirical system is modified to accommodate our data limitations, but the modification does not distract us from the focus of this study. The partial effects of parental time allocation on the child's obesity-related health outcome can still be explored.

We start with simple linear specifications for the empirical system and examine the identification issue. Our empirical system is a general triangular system with cross-equation correlations considered. The IT3SLS is chosen as our estimation procedure to obtain consistent and efficient results. As it is common in cross-sectional analysis that the instruments are likely to be weak, we will present both ITSUR and IT3SLS results to access robustness across these estimators.

The following chapter will provide a detailed description of our data set collection, including the sampling process and survey instruments.

CHAPTER V

DATA AND SUMMARY STATISTICS

This study utilizes a data set collected through a multi-disciplinary project at Texas A&M University entitled "Parental Time, Role Strains, Coping, and Children's Diet and Nutrition". The data set not only covers sociological aspects of the family, financial structure information and demographic details, but also provides dietary intake details and two-consecutive-day time diary records. Another unique aspect of this data set is that the above detailed information is available for each participating member of the household (two parents and one child).[31]

5.1. Data Collection and Survey Instruments

As indicated in the introductory chapter, a desirable data set for exploring the impacts of the parental time allocation and other parental factors on the children's health outcomes and the potential differences between fathers and mothers' marginal effects should not only include children's health status and nutrient intake but also have detailed parental time diary records on individual levels. Unfortunately, no existing data set has the required degree of richness to directly associate all these variables at the individual level.[32]

[31] This is for the two-parent household case. In our data set, we also have some single mother samples.
[32] This section is based on the project report titled "Parental Time, Role Strain, and Children's Fat Intake and Obesity Related Outcomes." This report is submitted to the Economic Research Service, USDA.

5.1.1. Data collection overview

The data set used in this study was collected between July 2001 and June 2002. The data were drawn from over 300 households in Houston (MSA), Texas. The sample was generated through random digital dialing. The goal was to obtain data from one child and both of that child's parents in dual-headed households or from one child and that child's mother in single female-headed households. The survey only covered children of age 9 to 11 or 13 to 15. Obtaining detailed data from children under the age of 9 using complex survey instruments is problematic (Crocket and Peterson). Furthermore, the nutrition literature suggests excluding 12-year olds because this is the age at which many children undergo puberty, which can greatly influence their diet intake and outcome measures. Crocket and Peterson also point out that as children progress through adolescence, the parental influence will begin to wane. So the data set contains these two age-groups in order to explore the waning parental influence on children's diets and health outcomes as they get older.

5.1.2. Survey instruments

Details of the data collection and instruments can be found in the project report (McIntosh et al.). The data set has individual information on two parents and one child for each household. Six survey instruments, grouped under three general headings, were used in the collection of the data.

1. Parent's telephone interview.[33] Each parent was interviewed by phone using a standard set of questions to determine their employment status, work type and work schedule. The interview questionnaire also includes work environment assessment questions to measure work flexibility, work control, and work commitment and the work-home role conflict for measuring work-to-home spillover. This interview also covers parenting styles (e.g., parental food control, parental feeding styles), parental concern about children's eating habits, and parent's self-reported health status along with the standard family socio-demographics.

2. Parent's self-administered questionnaire with time diary.[34] The questionnaire was designed to obtain both sociological and economic information from each parent. For the sociological information, each parent was asked his/her parenting strategies. With regard to the economic aspects, information about the individual parental sources of income and the household's expenditure patterns was gathered.[35] Also, parental time allocation pattern data over two consecutive days were gathered through time diaries.

3. Children's questionnaire, 24-hour dietary recall, 24-hour activity record, physical exam, 2-day diet record, 2-day activity record. The child interview consisted of three parts.[36] First, the interviewer went through the questionnaire with the child to complete the questions pertaining to the child's perception of his/her parents' parenting style, his/her relationship with his/her parents, family meal practice, the child's self-

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[33] Each parent was interviewed over the phone separate from their spouse and the interview lasted about 45 minutes.
[34] The field interviewers went through the questionnaire and time diary with the parents at their home and the instruments were left with them to be mailed back after completion.
[35] The data set does not have information on the individual expenditure.
[36] The interview time ranged from 45 minutes to 1 hour and 45 minutes. In rare cases, the interview took place in public facility or private home chosen by the parents.

esteem, personal health habits (e.g., dietary behavior and exercising frequency), work for pay experience and socio-demographic background.

Second, the children participated in a 24-hour dietary recall and a 24-hour activity recall under the guidance of the interviewers. The children were then instructed to be able to maintain a two-day diet record and a two-day activity record. The food record data were transformed into the child's nutrient intake values through the Food Processor.

Lastly, the field interviewers took the child's anthropometric measurements.[37] The child then completed the Tanner scales in order to obtain an indication of their pubertal status.[38] The child was given an envelope with the Tanner drawings and instructed to go into another room, circle the drawing that most closely resembled their body type, and return the Tanner drawings in the sealed envelope to the interviewer.

Details on survey respondent incentives and compensation plans can be found in the project report.

5.2. Data Specification

Chapter IV presents the empirical system for our estimation. In this general triangular system, we utilize the collected data set to specify sixteen variables: $(X_f, T_f^F, T_f^M, T_C^F, T_C^M, H, Y^F, Y^M, E_H, E_P, E_W, \mu, k^F, k^M, T^F, T^M)$. Among these sixteen variables are six endogenous variables and ten exogenous variables indicated by the theory.

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[37] The anthropometric measures include sub-scapular and triceps skinfold thicknesses, waist and hip circumference, height, weight.
[38] Tanner scale is used to determine the growth and sexual development of the child interviewed. Please refer to the project report by McIntosh et al. for detailed discussion on this.

Table 1 reports detailed descriptions of variables used in the empirical analysis including variable names, definition descriptions, and units. The table presentation breaks the variables down into dependent and independent variables. The empirical analysis explores the system in two ways: (a) estimate the system using the whole sample which pools both age groups (9-11 year old children and 13-15 year old children) together and adds one dummy variable, "Age", to examine the age effect; (b) break the whole sample down into two subsets by the two age groups to examine the separate parental effects on each group.

5.2.1. Household expenditure and individual total income

As mentioned before, our collected data set does not have individual parent's expenditure information. The empirical model is modified according to this limitation to include only the household food expenditure, X_f. During the interview, both parents were asked individually to provide monthly dollar amounts spent by the household on several expenditure categories. Among those categories, we find three food-related categories: (a) money spent on groceries and other food items eaten at home; (b) money spent on take-out and food delivered eaten at home; (c) money spent on going out to eat. In addition to dollar amount information, both parents were asked whether they were usually in charge of making the purchase in this expenditure category.

The household expenditure amount for food, X_f, is generated from this information. For each of the three food-related expenditure categories, we have information provided by each parent. If only one of the parents indicates that he/she is the one who usually makes decisions on the purchase and he/she provides non-missing data on the dollar amount, then this dollar amount is treated as the household monthly expenditure on this food-related category. If both parents say yes or both say no to the question on whether he/she is in charge of making purchase decisions, then the household expenditure amount in this category is the average of the expenditure amounts reported by both. The total household food expenditure will be the sum of the three expenditures on the three food-related categories.

Also, due to the data limitation discussed before, the empirical model treats the market working hours as predetermined and includes only the individual total income rather than wage rates and unearned incomes. Each parent's total income, (Y^F, Y^M), is the reported individual total income dollar amount or the sum of earned income and unearned income.

5.2.2. The child's obesity-related health indicator

The effect of parental time allocations on the child's obesity-related health outcome, *H*, is the focus of this study. "The degree of obesity is best defined by the body mass index (BMI, weight in kg/(height in m)^2" (Hoffman and Sawaya, pp.657). In general, a person is considered to be unhealthy (overweight) when the BMI score is greater than 25 and is defined as obese if the BMI score exceeds 30. Unlike adults, however, where overweight or obesity is based on a defined BMI score, childhood overweight is identified by one's BMI in relation to age and gender (Cole et al.).

For this study, we use a continuous BMI score as the indicator for the child's obesity-related health outcome, *H*. BMI scores were calculated from the child's weight and height anthropometric measurements according to the BMI definition.

5.2.3. Parental time measurements

There are two parental time allocation variables that enter the child's obesity-related health production function, the parental time spent in food preparation, (T_f^F, T_f^M), and the parental time spent with the child, (T_C^F, T_C^M). These variables were generated from the two-consecutive-day time diary records provided by both parents and are in minute units.

Parental time spent in food preparation includes not only the time spent in preparing meals, drinks and snacks, but also the time spent in food clean-up and take-out food purchasing. The two-day time diary records also give us information on time spent in grocery shopping and meal/shopping list planning, but we do not include this time in the food preparation time variable since the time information in the data set is limited to the two-day window. A household may or may not go shopping during the survey period, thus, including grocery shopping and meal/shopping list planning time would lead to a large variance in the time spent in food preparation.

Another time allocation variable is the parental time spent with the child. We will mainly explore its influence on the child's obesity-related health outcome and the different impacts of the father's time and the mother's time. This time variable represents the average time per day the mother and father each spend with the child. This variable is derived by subtracting the total of all parental time not spent with the child from the total available time in a day (1440 minutes).

It should be mentioned that this measure does not distinguish between the time spent in activities that contribute to energy intake (e.g., consuming food) and those that qualify as energy expenditure (e.g., exercising). Although this measure does capture the general quantity of parental time spent with the child, it cannot fully depict the quality of the time. The quality of the time is the quality of interaction between parents and the child during their time together and the parents' degree of engagement.

The last parental time variable is the total non-working time available to each parent, (T^F, T^M). This variable is residual time and is equal to the total time per day (1440 minutes) minus parental time spent in market work per day.

All these parental time allocation variables are averaged from the two-day records using primary activities as the criteria. Because our empirical model has work environment, E_W, as an exogenous variable, our sample is a subset of the entire project data set and covers only those households with two working parents. In our sample, the two-consecutive-day survey period varies across individual households and both weekday and weekend time allocation data are mixed in the sample. The household could be interviewed during two weekdays, or over a weekend, or possibly one weekday (Friday) and one weekend day (Saturday). There is an indicator in the data set to distinguish between weekday and weekend time devotion.

However, weekday and weekend time distinction is not an issue of major concern since parental time devotion choices are expected to have different patterns as the total available non-working time changes. The real issue is working day versus non-working day. In our sample, there are working parents who work full-time, part-time or other scheduled working times, so the weekend does not necessarily correspond to non-working day for all parents in the data set.

This issue brings out an important point: there are potential differences in working day and non-working day parental time allocation decisions. In order to explore them, we create two dummy variables, (D_f, D_m), for the father and the mother to identify working days and non-working days. The dummy variable equals 1 when the two-day time diary survey period covers at least one working-day (the reported working time is nonzero for at least one day) and 0 if both days are non-working days.[39] These two dummies will be added along with the total non-working time variables to all five reduced-form health input demand equations.

The generated time allocation variables should represent working day time devotion patterns when at least one working day time allocation is reported during the survey period. They should capture non-working day time devotion patterns when the two days are both non-working days. A discussion of how those variables are generated follows.

The average working time variable, T_w, is generated by utilizing an indicator in the data set which comes from a question in the telephone interview part of the survey. The parent was asked the following question: "What days of the week do you normally work?" If the parent answers that his/her work schedule is Monday through Friday or

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[39] The detailed summary statistics will be presented later.

Monday through Friday plus some weekends, we created an indicator, *i*, to denote that the parent works at least five weekdays. Among the total working parents sample we collected, 84% of the fathers in the sample and 71% of the mothers in the sample worked at least five days a week.[40] If the parent did not provide an answer but he/she was employed at that time, the assumption is that he/she works weekdays.[41] Among the 237 working fathers in the telephone interview data, there are only 4 records have missing values on this question or only 1.7% of the sample. Among the 211 working mothers in the sample, there is only 1 record has missing value on this question.

The average working time per day is generated as follows:

- For those reporting non-missing (including zero value) working time for two days and those two days are one weekday and one weekend day, the mean of the two days is taken as the average working time if both days have nonzero values; if one of them has nonzero working time and the other has zero working time, then the nonzero value is used as the average working time; if both reported values are zero, the average working time will be zero meaning that the two days that the parent was interviewed were non-working days.[42]
- If the two days are both weekdays, then the indicator, *i*, will be used to identify whether those two days should be work days or not. If the answer is yes, then the mean will be used as the average working time. If the indicator shows that

[40] Working fathers and working mothers are the ones who reported worked nonzero hours during the week before the interview period.
[41] The sample size of this study is small and the degree of freedom is of concern. So we try to preserve as many data points as possible.
[42] In the working parents subset of the data set, there are 13 fathers and 25 mothers who reported zero working time in both two days. The detailed summary statistics for the empirical data set used in the analysis will be discussed later.

the person does not work regularly during weekdays, we treat the average working time as missing.[43]

So the total available non-working time, (T^F, T^M), is the result of subtracting generated working-time from the total amount of time in a day.

The other two parental time allocation variables are generated in the same fashion. If the two days have nonzero working time values and cover weekday and weekend, then the average of the two time allocation categories (parental time spent with the child, and the parental time spent in food preparation) will be used as variable values. For those have only one nonzero working time value, only the time allocation patterns on that day are counted as variable values. So generated parental time allocation variable values will capture working-day patterns if the two-day survey period covers at least one working-day and will represent non-working day patterns if the survey period covers two non-working days for the parent.

5.2.4. Other exogenous variables

In the empirical model, there are several exogenous variables: environmental variables, the child's type variables, and the parents' type variables.

The environmental variables cover three aspects: home, peers and parent's work. These variables capture home and societal influences on the child's obesity-related health outcome and the parental work stress and work commitment assessment. The

[43] If the two days are all weekend days, then the mean will be assumed to be the average working time. The percentages are very low: among the whole data set, only 4 fathers and 5 mothers were interviewed only in weekends.

home environment, E_H, is captured by a factor, created from the principal factors factor analysis.[44] This factor is work-to-family spillover and depicts the home environment caused by work-related negative impacts such as no energy, no time for family and poor father/mother role performance. Devine et al. suggest that the mother's work stress and work-to-family spillover may cause more family meal skipping, meal irregularity and more take-out food purchasing. A high score of work-to-family spillover indicates that the parent is more likely to experience work-to-family spillover (conflict between family and work roles caused by work demand).

The child's peer environment, E_P, enters the model to depict peer pressure. In our survey, the children were asked whether or not they felt that others thought they were overweight. This question is used to generate the peer pressure dummy variable. The dummy variable is 1 if the child said yes (there existed peer pressure on the child's self-image), 0 otherwise.

The parent's work environment, E_W, captures the market work direct influence on the parents' utilities. This variable indirectly influences the child's health outcome through optimal solutions. We use two variables to depict this aspect: work flexibility and work commitment of each parent.

Work flexibility shows how flexible the parent's work schedule can be (in hours and in days). Fenwick and Tausig demonstrate that such flexibility may increase satisfaction with work and with life in general, and improves health status. Several studies show that control over work schedule may have emotional and physical

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[44] Detailed factor analysis results can be found in the project report (McIntosh et al.).

consequences and may contribute to tensions in spouse relationships and parent-child interactions (Baker; Menaghan; Rau Triemer). We used two questions in the survey to capture the working hour flexibility and working day flexibility for both parents. Those variables are rank variables: they reflect inflexibility, some flexibility, and high flexibility. The value ranges from 1 to 3 or from inflexible to highly flexible. We directly use these ranks as indicators of work flexibility.

Work commitment captures the importance parents place on their jobs relative to other roles in life. Laedwig and McGee found that work commitment is positively related to spouse conflict. In our survey, parents were asked whether work is the most important thing in their lives. They chose from strongly disagree, disagree, neither agree/disagree, agree, and strongly agree. The answer ranges from 1 to 5 indicating the parent's commitment to work from very low to very high. We directly use these ranks to capture the degree of work commitment.

The child's type variable, μ, helps to capture the genetic and sociological aspects of the child. It is a vector of variables. We used the following variables to determine it: the child's gender, the child's puberty stage (if the value is 1 means that the child is post-puberty; 0 means that the child is pre-puberty), the child's ethnicity and the child's activity level. The child's activity level was generated from a question asking how many times in the past 14 days the child has done at least 30 minutes of hard exercise.[45] The ranking variables (it has five ranks) are generated into four dummy variables with no exercise at all as the base. For the pooled model estimation combining both age groups,

[45] The hard exercise refers to those exercises that can make the child breathe heavily and the heart beat fast, such as playing basketball, jogging etc. It includes physical education class activities.

one dummy variable is added to the child's type variable to indicate the age group. The dummy variable is 1 if the child is 13 to 15, and 0 otherwise.

The parent's type variables, (k^F, k^M), are used to depict the heredity of the child and the power difference between parents. The parent's individual BMI scores act as heredity measures. To determine parental power differences, we use four dummies generated from four decision power related questions: who decides on whether to buy groceries; who decides on whether to eat out; who decides on how much to spend on groceries; who decides on how much to spend on eating out. We first create four rank variables as follows for the father and the mother, respectively: the value is 2 if the parent indicates that he/she is the only decision maker; the value is 1 if the parent indicates that he/she makes the majority of decisions; the value is 0 if the parent reports that he/she and other family members equally make decisions; the value is -1 if other family members make more decisions; the value is -2 if only other family members make decisions. Then the power difference dummies are created from the differences between the father's answers and the mother's answers.

5.3. Summary Statistics

This section reports the descriptive statistics for the pooled sample (Table 2) and the two separate samples, respectively (Table 3 and Table 4). The mean, standard deviation, minimum and maximum and the coefficients of variation (CV) will be discussed. The CV represents an attribute of a distribution and is a statistical measure of the deviation of a variable from its mean. It is calculated by dividing the standard deviation of the given variable by its mean and can be represented as a percentage: CV%. It is helpful in comparing the variation of populations that have different units, so it will be used to compare some of the variables across the two age-group subsamples.

5.3.1 Summary statistics for the pooled model

The entire data set collected through the project has a maximum of 325 household records and each household record has three sets of data: the father's data, the mother's data and the child's data. There are numerous combinations of missing information within the data set since different combinations of questions were not answered by different household members. When the regression is run using the full data set, the household records that have missing data for the variables of interest are dropped out of the sample automatically. We report only the data set that is actually used in the analysis which includes all households that have complete information from both parents and the child for the variables of interest. The sample size will be the same for all variables within the same model.

For the pooled model, we do not separate the sample into two age groups. Instead, one dummy variable[46] is added into the system to identify the age effects. The summary statistics are reported in Table 2. The sample size for the pooled model analysis is 127 observations. Out of the total 325 households, 127 households have complete information for all the variables in the empirical system. Because we have work-related

[46] The dummy variable, Age, have value of 1 if the child is of age 13 to 15 and 0 otherwise.

variables in the empirical system, such as work environment and work to home spillover, the sample represents only households with two working parents[47].

The average total household monthly expenditure on food is about $688 with a huge variation: the minimum is $210 and the maximum is $1579. The fathers' average total income is larger than the mothers' average total income and also is of less variability compared to the mothers'. The CV of the fathers' income is 68% while the CV of the mothers' income is 104%.

In the sample, mothers devote more time to the family compared to fathers on average. Mothers spend an average of about one hour a day in meal and drink preparation, meal clean up and purchasing fast food (65 minutes), while fathers spend an average of 21 minutes. The average daily amount of time mothers in the sample spend with their children is about one and a half hours (91 minutes) while fathers spend an average of one hour and eighteen minutes (78 minutes) a day. Fathers' time spent with the child has a large range compared to mothers' from 0 hours to 16 hours a day.

It is a consistent pattern that fathers' time devotion to the family (food preparation and time with the child) has larger variability. The CV of mothers' food preparation time is 83% while the CV of fathers' is 121%. The CVs of parental time spent with the child also show that fathers' family time devotion has larger deviation compared to mothers' (father: 143%, mother: 101%). Meanwhile, mothers have more available non-working time per day on average compared to fathers and with less variability. In the sample,

[47] The whole data set includes single mother households, and one working parent households.

90% of the fathers and 80% of the mothers reported at least one working day time allocation pattern.

The average score for the children's BMI is about 21 with a minimum of 14 and a maximum of 45. Children's BMI standard is different from that of adults. The children's BMIs should be compared to the BMI-for-age charts (one for boys and one for girls) provided by The National Center for Health Statistics and the National Center for Chronic Disease Prevention and Health Promotion. Each chart contains a series of curved lines indicating specific percentiles. The child is considered to be "at risk of overweight" if the BMI-for-age is between the 85th percentile and the 95th percentile; if it is at or above the 95th percentile, the child is "overweight". After age 20, the BMI cut-off points for "at-risk for overweight" and "overweight" are the same as for adults. The children's BMI cut-off points vary according to the children's gender and age. So the children's BMI mean does not have clear cut-off points to compare. Fathers have higher average BMIs than mothers (27 vs. 25). However, both means belong to the "overweight" category ($25 \leq \text{BMI} < 30$). Mothers have more variability in BMI than fathers.

Most of the sociological variables indicate only ordinal changes in the given variables. Work-to-home spillover is a factor generated from the principal factors factor analysis and the unit is difficult to interpret. The higher the spillover score, the more likely the person is experiencing more work-to-home spillover. Work flexibility and work commitment variables are rank variables and hard to compare and interpret from summary.

In our sample, 10% of the children are experiencing a certain degree of peer pressure on their self-esteem, 48% are boys, 55% of the children belong to the 13 to 15 age group, 80% of the children are non-Hispanic white, 11% are Hispanic, 88% of the children are pubescent, and 95% of the children have at least one day of active exercise in the past 14 days.

5.3.2. Summary statistics for two subsamples

We expect parental influences to have different effects on children as compared to adolescents. Therefore, it is logical to separate children of age 9 to 11 and children of age 13 to 15 to explore the potential differences. After splitting the sample, 57 households have children aged 9 to 11 and 70 households have children aged 13 to 15. Table 3 and Table 4 report the summary statistics for these two age groups, respectively.

The average monthly household food expenditure amount is of the same variability across the two subsamples with the average of $676 in the younger children sample and $697 in the older children sample. All fathers have higher average total income than mothers in both subsamples. Parents with younger children have a higher deviation in total income compared to those with older children and fathers have less variability in their total income compared to mothers in both samples. In the younger children sample, the CV of fathers' income is 73% and the CV of mothers' income is 112%; for the older children sample, fathers' income CV is 63% and mothers' income CV is 100%.

On average, parents with older children spend relatively more time in food preparation compared to those who have younger children. The difference is larger in father's food preparation time devotion: fathers with older children devote an average of 25 minutes a day in food preparation while fathers with younger children devote an average of 16 minutes a day. Also, there is less variability in father's food preparation time allocation and more variability in mother's food allocation time devotion in the older children sample compared to the younger children sample. Parents spend more time with their children in the younger group on average. In the younger children sample, fathers spend an average of one hour and twenty-three minutes per day (83 minutes) with their children while mothers spend around two hours per day (113 minutes) with their children; in the older children sample, fathers spend about one hour and fifteen minutes per day (75 minutes) on average with their children and mothers spend about one hour and thirteen minutes (73 minutes). There is more variability in parents' time spent with children in the older children sample compared to the younger children sample. Mothers spend more time with their children compared to fathers when their children are of age 9 to 11. Fathers spend relatively more time with their children compared to mothers on average when the children are of age 13 to 15. Meanwhile, the parents all have more non-working time available for the family on average in the younger children sample compared to the older children sample. The percentages of parents reporting at least one working day are almost the same across the two subsamples.

The children's BMI scores in both subsamples have similar variability (20% CV in the younger children sample, 22% CV in the older children sample). The younger children sample has a maximum BMI of 29 and the older children sample has a maximum BMI of 45. These two maximum scores well exceed the 95th percentile BMI-for-age cut-off points for both boys and girls.[48] The parents' BMI scores have similar means across the two subsamples with the older children sample exhibiting higher variability in both parents BMI scores compared to the younger children sample.

On average, both parents have more flexible work schedules (in terms of work-day and work-hour) when their children are of age 9 to 11 and experience less work-to-home spillover. Mothers put their work priority lower on average when their children are younger while fathers exhibit the opposite pattern.

Both subsamples have similar percentages of children experiencing some degree of peer pressure on their self-esteem. There are 42% boys in the younger children sample and 53% boys in the older children sample. About 74% of the younger children in the sample are non-Hispanic white and 18% are Hispanic. About 84% of the older children in the sample are non-Hispanic white and only 6% are Hispanic. The percentages of the children who participate in active exercise at least one day in the past 14 days are similar across the samples.

5.4. Chapter Summary

This chapter presents detailed information on the data set used in the empirical analysis. This unique data set covers several aspects of household dynamics: financial information, parenting styles, sociological factors, family meal practice, nutrient intake

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[48] According to the BMI-for-age charts developed by the National Center for Health Statistics, the 95th percentile for boys of age 11 is 23.2 and girls of age 11 is 24.1, the 95th percentile for boys of age 15 is 26.8 while for girls is 28.1.

patterns, parental time allocation information and children's time allocation information, along with the socio-demographics. This complex data information covers individual household members and provides us with individual-level parental information and child health outcome data. This information makes it possible for our empirical analysis to explore parental influence and the potential differences between fathers and mothers. The data collection overview and six survey instruments are discussed. This section draws from the project report by McIntosh et al.

In order to present estimation results clearly in the following chapter, the variable generation processes are discussed in this chapter. Sixteen variables of interests are defined using the information collected in the data set. The household monthly food expenditure amount is generated mainly by using the decision-maker's reported amount. Individual income is the sum of wage income and non-wage income. The parental time allocation variables are generated in a specific way in order to capture the working-day time devotion pattern if the time diary data reflects information from at least one working day; otherwise the time allocation variables will depict the non-working day pattern. The children's BMI and the parents' individual BMI are calculated according to the BMI definition. There is one factor generated using factor analysis. The work environmental variables are all ranking variables which reflect ordinal changes. The other exogenous variables such as peer pressure, activity level, and parents' decision power variables are discussed as well as the socio-demographics.

Finally the summary statistics of the variables of interests are presented for the pooled model and the two separate age-group models.

The following chapter will present empirical estimation results for the children's obesity-related health production function and the other five health input demand functions. The pooled model, the younger children (of age 9 to 11) model and the older children (of age 13 to 15) model will all be included, and the IT3SLS and ITSUR estimators will be compared to examine robustness.

CHAPTER VI

ESTIMATION RESULTS

The previous chapter reported data descriptions and summary statistics for those variables used in the empirical analysis. The empirical chapter (Chapter IV) derived a general triangular system with five reduced-form health input demand equations and one structural children's health outcomes production equation.

This chapter presents estimation results for the triangular system we developed using the data described in the previous chapter. Because the focus of our study is on parental influences on children's obesity-related health outcomes, the empirical results for the child's obesity-related health production function presented in the empirical setup chapter (Chapter IV) are the main results we will examine. The reduced form health input demand functions results will be discussed as well. The pooled model estimation results will be presented separately while the two subsamples' estimation results will be compared. Also the IT3SLS and ITSUR results will be compared to examine robustness across alternative estimators.

6.1. Obesity-Related Health Production Function Estimation Results

The empirical setup chapter (Chapter IV) presented a triangular system used in this empirical analysis. In that general triangular system, there is only one structural equation which is the child's obesity-related health production function:

(4.1) $H = H(X_f, T_f^F, T_f^M, T_C^F, T_C^M, E_H, E_P, \mu, k^F, k^M)$.

The estimation results for this equation will provide the marginal effects of parental factors on the children's health outcomes. We choose the semi-log (the left hand side variable, *H*, is in log form and the other variables remain unchanged) functional form for this production function and the linear functional form for all reduced form health input demand equations. The functional form selection should be considered for future study.

There are three types of explanatory variables in the health production function that can be grouped as follows:

1. <u>Economic Variables</u>: the household total monthly food expenditure, X_f; the parent's time spent in food preparation (including meal clean up and fast food purchasing), (T_f^F, T_f^M); the parent's time spent with the child (not separating out the individual time and joint time), (T_C^F, T_C^M).
2. <u>Sociological Variables</u>: the parent's work-to-home spillover factors which capture the home environment, E_H; the peer pressure the child is facing, E_P.
3. <u>Control Variables</u>: the child's gender, ethnicity, age (only enter into the pooled model), activity level; the parent's BMI scores, the decision power difference between the father and the mother, (D_1, D_2, D_3, D_4).

The results will be presented in these categories.

6.1.1. The Pooled Model

The parameter estimation results and standard errors are reported in Table 5.

<u>Economic Variables</u>: For these five economic variables, there exist large discrepancies across the alternative estimators. Four variables appear statistically

significant at the 5% significance level in the ITSUR results and none is significant in the IT3SLS results even at the 10% significance level. The magnitudes of the estimates are larger in ITSUR results than those in IT3SLS results except for the total household monthly food expenditure. All the signs are consistent across the two alternative estimators. In future work, the instruments will be tested more.

Now let us take a look at the significant variables in the ITSUR estimation. The total household monthly food expenditure has positive impact on the children's BMI outcome. A $1,000 increase in the household monthly food expenditure will lead to a 0.1 log unit increase in the children's BMI which is about a 1.3 unit increase in BMI score. Both fathers' and mothers' parental food preparation time are positively related to children's obesity-related health outcomes. Every 100 minute increase in fathers' food preparation time is associated with about a 0.3 log unit increase in the children's BMI while the 100-minute increase in mothers' food preparation time is associated with a 0.6 log unit BMI increase in the children. The children's BMI in log form tends to decrease when the parents spend more time with their children. The fathers' time spent with their children has statistically significant impact: for every additional 100 minutes fathers spent with their children, their children's BMI score decreases by around 1 unit.

<u>Sociological Variables</u>: The estimation results exhibit consistency in signs, magnitudes and significance across the alternative estimators. The mothers' work-to-home spillover factor tends to be positively related to the children's BMI outcomes.[49] Both IT3SLS and ITSUR estimators show that for every one unit increase in the

[49] The significance level is 10%.

mothers' work-to-home spillover, there will be a 0.05 log unit increase in the BMI score, or approximately a 1.1 unit BMI score increases. Also both estimates confirm that peer pressure contributes positively to the children's obesity-related health outcomes. Children who reported facing peer pressure on their self-esteem tend to have higher BMI compared to those who did not report it and the impact is statistically significant.[50] The possible endogeneity associated with peer pressure should be explored in future research.

Control Variables: The signs, magnitudes, and significance are fairly consistent across the estimators. Statistically significant results are discussed here. The children in the older age group (of age 13 to 15) exhibit higher BMI than the younger children (of age 9 to 11). Those children who participated in active exercise for 30 minutes at least one day in the past 14 days tend to have higher BMI compared to those who had no active exercise at all in the past 14 days. It may be that those exercise effects are out-weighted by the energy intake effects.[51] Mothers' BMI has a positive relationship with their children's BMI. For each unit increase in mothers' BMI, there will be a 0.01 log unit increase in their children's BMI, or about 1 unit BMI score increase.

6.1.2. Children of age 9 to 11 vs. children of age 13 to 15

Table 5 also exhibits detailed parameter estimation results and standard errors for these two subsamples. The IT3SLS estimators have much less significant results compared to the ITSUR estimators. Also, in contrast to the pooled model, the two estimators now exhibit signs changes.

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[50] The peer pressure is self-stated data.
[51] Children who exercise more may tend to eat more afterwards.

Economic Variables: The IT3SLS estimators show no significant effects among the economic variables. The sign changes for only one statistically significant variable across the estimators: the marginal effect of the fathers' food preparation time changes from positive in the pooled model ITSUR estimates to negative in the younger children model ITSUR estimates. Only statistically significant results are discussed here.

When considering the analysis of the two age groups separately, the total household monthly food expenditure amount only has significantly positive impact on the younger children's BMI outcomes. The magnitude is a little greater than the marginal effect in the pooled model, however, the difference is very small. The children's BMI scores increase about 0.2 log units (about a 1.6 unit BMI score increase) with every $1,000 increases in food expenditure. There is only one time allocation effect that appears to be significant in the children of age 9 to 11 subsample while two more marginal effects show up in the older children group. Fathers' and mothers' food preparation time allocations do not have significant impact on the younger children's BMI while they do contribute to the older children's BMI outcomes. The BMI of children of age 13 to 15 will decrease 0.2 log units for every 100 minutes of additional food preparation time fathers devote while the additional 100 minutes mothers allocate to food preparation will bring a 0.1 log unit increase in their children's BMI. Mothers' time spent with their children has consistent negative marginal effect on their children's BMI outcomes across both age groups. The additional 100 minutes mothers devote to their children will bring about a 1 unit BMI decrease in their children's BMI scores when their children are young; the marginal effect increases to a 1.3 unit decrease in their children's BMI scores per 100 minutes increase when their children are older. The marginal effect of fathers' time spent with their children changes from a negative impact to a positive impact when their children are of age 13 to 15. However, this marginal effect is not significant in both age groups.

Sociological Variables: Fathers' work-to-home spillover factor does not have a significant marginal effect on the children's BMI outcomes in either age group and across the estimators. A one-unit increase in mothers' work-to-home spillover brings about a 0.09 log unit increase in their children's BMI. Peer pressure plays a consistent positive role in both age groups with the impact slightly higher in the older group.

Control Variables: There are some sign changes across the estimators, however, they all occur in insignificant variables. Boys tend to have higher BMI than girls when they are of age 9 to 11. Older children participating in active exercise for 3 to 5 days in the past 14 days exhibit higher BMI than those who participated in none. Mothers' BMI plays a consistent positive role in their children's BMI outcomes with the magnitude of the marginal effect decreasing a little for the older group.

6.1.3. Summary for the health production function results

There exist discrepancies across the two estimators (IT3SLS and ITSUR) especially in terms of the numbers of the significant variables. The main concern for the IT3SLS estimation is whether the instruments we have satisfy the exogeneity condition and the relevance condition. In order to satisfy the relevance condition, the model not only needs to have as many instruments as the regressors but also needs to have instruments that are highly correlated with the endogenous variables. If the instruments are weak, the finite sample properties of the IV estimators will not be preferred over the OLS estimators (Park and Davis). In our empirical analysis, the auxiliary R^2 from regressing the endogenous variables on the given instruments range from 0.28 to 0.41 for the pooled model, from 0.48 to 0.67 for the younger children model, and from 0.38 to 0.71 for the older children model. However, the auxiliary R^2 may be misleading in multivariate models. Future studies should utilize more sophisticated tests to evaluate and select the instruments.

Among the significant marginal effects, mother-related variables show more influence on the children's BMI outcomes compared to father-related variables. For both age groups, mothers' time spent with their children has negative marginal effects on their children's BMI at the 5% significance level. Fathers' time spent with their children only has significant negative effect for the pooled model. Among the work-to-home spillover factors that capture the home environment, only the mothers' spillover factor positively influences the children's BMI in a statistically significant way in both the pooled model and the younger children model. Meanwhile, the fathers' BMI does not play any significant role and the mothers' BMI consistently shows a positive influence in the children's BMI outcomes in all three models.

When children are of age 13 to 15, the fathers' food preparation time devotion has opposite marginal effect compared to the mothers', i.e., the fathers' food preparation time is negatively related to the children's BMI while the mothers' food preparation time is positively related to the children's BMI. The monthly household food expenditure amount contributes positively to the children's BMI in the pooled model and the younger children model. The peer pressure variable consistently plays a significant positive role in all three models.

Another issue that needs to be explored in future work is the dependent variable of this obesity-related health production function being captured by the child's BMI score. This dependent variable is a ratio of the child's weight over height squared. As Farris, Perry, and Ailawadi point out, it is recommended that one model the components of the ratio instead of only modeling the ratio itself. For example, if parental time spent with the child brings positive impacts both to the child's weight and the child's height, and if the denominator marginal effect equals the numerator marginal effect, then the total ratio effect on the BMI score appears to be zero. It is incorrect to conclude that parental time spent with the child has no effect on the BMI ratio, rather it is just that the effects offset. So the implication in our analysis is to model the child's weight and height squared separately with the same right hand side variables entering the BMI production function in order to capture different marginal effects on the BMI components.

6.2. Reduced Form Health Input Demand Functions Estimation Results

In the general triangular system we developed previously, there are five reduced form demand functions for health inputs: total household monthly food expenditure, parental food preparation time, and parental time spent with the child. These demand functions are final reduced form equations derived from the theoretical framework and have no endogenous variables in the right hand side of the equations. Theoretically, this means that the IT3SLS and ITSUR will yield similar estimation results, so in this section we will present only the ITSUR estimators.[52]

Final reduced form equations derived from the same theoretical framework have the same explanatory variables, so these five demand equations all have the same right hand side exogenous variables. Table 6, 7 and 8 report the five equation estimation results for the pooled model, the younger children model, and the older children model, respectively. This section focuses on discussing the statistically significant marginal effects.

6.2.1. The pooled model

Table 6 presents detailed estimation results and standard errors for the pooled model five health input demand functions.

Economic Variables: Both parents' individual total incomes have a positive relationship with the total household monthly food expenditure. Every additional $1,000 increase in the fathers' total income brings about a $1.70 increase in the total household monthly food expenditure, while each additional $1,000 in the mothers' total income brings about a $1.78 monthly household food expenditure increases.

Mothers' individual total income has opposite effects on the fathers' food preparation time and the mothers' food preparation time: the fathers' food preparation time will increase by 0.2 minutes for every $1,000 increase in the mothers' income while the mothers' food preparation time will decrease by 0.4 minutes. This may reflect the

[52] The IT3SLS and ITSUR are the same in terms of signs and significance and the magnitudes only differ by a very small amounts.

complementary effect of the household members' time and money resources, i.e., the more time fathers can spend in household related activities, the more time mothers can spend in market work. One puzzling result is that working mothers spend more time with their children during their working days.

Sociological Variables: Every one-unit increase in the fathers' work-to-home spillover will bring $65 more household monthly food expenditure and result in mothers spending an additional 21 minutes with their children. The more flexible the fathers' work hour schedule is, the more food preparation time fathers will allocate; the more flexible the fathers' work day schedule is, the more monthly household food expenditures will be. There is no significant effect from mothers' spillover and work flexibility variables. Fathers' degree of job commitment is negatively related to the household monthly food expenditure, while mothers' degree of job commitment contributes positively to the household monthly food expenditure. Also, it is somewhat puzzling that the more committed mothers are to work, the more food preparation time the mothers will allocate resulting in fathers spending less time with their children.

Control Variables: There are only a few significant variables among the control variables. Some of the parental decision power variables show up. The more power the fathers have in deciding on how much to spend on groceries, the more the household monthly food expenditure will be. The more decision power fathers have about whether to eat out or not, the more time mothers will spend with their children; however, if fathers have more decision power in how much to spend while eating out, mothers will spend less time with their children.

6.2.2. Children of age 9 to 11 vs. children of age 13 to 15

Table 7 and Table 8 exhibit detailed parameter estimates and standard errors for the younger children model and the older children model, respectively.

Economic Variables: For the total household monthly food expenditure, the individual parent's total income impact changes along with the children's age. For the younger children model, each additional \$1,000 of mothers' income will increase the total household monthly food expenditure by around \$3.3. Fathers' income becomes important to food expenditures when the children grow older: every \$1,000 increase will result in \$2.8 more household food expenditure per month. For mothers' with children in the older group, their total available non-working time will contribute positively to the total household food expenditure.

In the younger children sample (Table 7), mothers' income does not have an effect on either fathers' or mothers' food preparation time allocation. Only an increase in fathers' total income will result in less time spent by fathers' in food preparation. For the older children sample (Table 8), every \$1,000 increase in mothers' total income will result in fathers spending 0.2 minutes more in preparing food, while mothers spend 0.6 minutes less in food preparation.

Regarding parental time spent with the child, the total incomes for the individual parent do not have a significant impact when the children are young. For the older children group, the mothers will spend 0.7 minutes less with their children for every \$1,000 increase in their total income. When the children are young, parental total available non-working time plays more of a role. Mothers will spend an additional 0.3

minutes with their children for every one-minute increase in the fathers' total available non-working time. Every additional minute of non-working time mothers have will result in fathers spending 0.2 minutes less time with their children and mothers spending 0.3 minutes more with their children. For the older children, fathers' total available non-working time contributes negatively to the mothers' time with the children. This also reflects the intra-household time resource substitution effect: the more time fathers have for household-related activities, the more likely mothers are to allocate their time less to household-related activities. For fathers with older children, fathers spend significantly less time with their children during their working days.

Sociological Variables: There are few significant sociological variables. The more flexible the fathers work day schedule is, the more monthly household food expenditures for the older children sample. In the young children sample, mothers' degree of work commitment is negatively related to fathers' food preparation time allocation; while for the older children sample, mothers work commitment contributes positively to their own food preparation time devotion. In addition, for the older children sample, the more flexible the father's work hour schedule is and the more committed to work the father is, the less time the mother will allocate to food preparation.

Mothers' workday flexibility is positively related to fathers' time with their children for both age groups. Fathers' work hour flexibility is negatively related to mothers' time with their children for the older children sample.

Control Variables: Households in the younger children age group with children who are experiencing peer pressure will have less household food expenditure and less mothers' time allocated to the children compared to households with children who are not experiencing peer pressure. The households with boys of age 13 to 15 spend less money on food per month than those households with girls in the same age range. Fathers allocate more time to food preparation and spend more time with their children if their children are young and participate in active exercise for at least 1 to 2 days in the past 14 days.

Fathers' decision power in whether to buy groceries or not has a negative relationship with mothers' time with the children in the younger children model and a negative impact on household food expenditure in the older children model. Fathers' decision power in whether to eat out or not has a negative relationship with household food expenditures for the younger children sample, and has a negative relationship with fathers' time spent with their children for the older children sample. For the older children sample, if fathers have more say so in the grocery expenditure amount, the household expenditure on food will increase and fathers' time spent with their children will increase also.

6.2.3. Summary for the health input demand functions results

Fathers' or mothers' own individual income appears to have a negative effect on their own food preparation time allocation. For the older age group, as mothers' own income increases their time with their children tends to decrease. This is consistent with the income and non-working time substitution relationship for a person's own resource allocation.

The results of the pooled model and the older children model indicate that fathers' non-market work time and mothers' total income are complements showing the time and money complementary relationship between parents. Stated in another way, fathers' non-market work time and mothers' non-market work time display a substitution relationship.

Parental total available non-working time is positively related to the two parental time allocation choices, especially for the young children sample. An increase in mothers' total available time will induce more mothers' time with their children and less fathers' time with their children. This, again, shows the substitution effect between parents' time resources.

6.3. Parental Time Marginal Effects

In the empirical results, fathers' and mothers' time spent with their children have negative impacts on their children's BMI outcomes, in general. In other words, parental time spent with their children will bring a positive impact to their children's health outcomes: $\frac{\partial H^*}{\partial T_C^i} \geq 0$.[53] The fathers' time with their children is a positive contributor to the children's BMI in the older age group, however it is not significant at the 10% significance level. The children's BMI is negatively influenced by mothers' time spent with them for both age groups when they are analyzed separately. In the pooled model the children's BMI will be negatively influenced only by the fathers' time spent with

[53] The higher the BMI is, the worse the child's health will be. So we can also us the (-BMI) to represent the health outcomes, *H*.

them. The signs are robust across estimators, however, the magnitudes and significances are not.

As the theory shows, we cannot sign the parental time marginal effects on the children's health outcomes without further assumptions. The comparative statics results derived in the theoretical chapter give us inequality (3.29):

$$(3.29)\quad \underset{(a)}{u_{T_C^i H}\cdot\frac{\partial H^*}{\partial T_C^i}}+\underset{(b)}{(u_{T_C^i t_E}-u_{T_C^i t_o})\cdot\frac{\partial t_E^*}{\partial T_C^i}}+\underset{(c)}{(u_{T_C^i t_f}-u_{T_C^i t_o})\cdot\frac{\partial t_f^*}{\partial T_C^i}}\geq 0\,.$$

Different quantity and quality of parental time devoted to the children will bring different marginal effects (they may be different in signs and magnitudes). The theory only allows the above combination effect to be signed because the parental time spent with the child variables enter more than on first order condition.[54] The left hand side of inequality (3.29) is composed of three different marginal utility impacts of parental time spent with the child:

1. Part (a): Health effect;
2. Part (b): Exercise (energy expenditure) process benefit/bad effect;
3. Part (c): Food consumption (energy intake) process benefit/bad effect.

In order to disentangle the health effect, we need to make enough assumptions on cross effects and magnitudes to be able to sign the combination of part (b) and part (c).[55]

We expect different marginal health impacts from mothers' time and fathers' time and use the home environment indicator in our model to try to capture parental time quality.

[54] Detailed discussion can be found in Chapter III.
[55] The details can be found in section 3.4 of Chapter III.

The parental time partial effect is decomposed as shown in Equation (3.28) in the theoretical chapter:

$$(3.28)\quad \frac{\partial H^*}{\partial T_C^i} = \frac{\partial H}{\partial N}\frac{\partial N^*}{\partial T_C^i} + \frac{\partial H}{\partial t_E}\frac{\partial {t_E}^*}{\partial T_C^i} = \underbrace{H_N \frac{\partial N^*}{\partial T_C^i}}_{(a)} + \underbrace{H_{t_E}\frac{\partial {t_E}^*}{\partial T_C^i}}_{(b)},\ i = F, M.$$

Part (a) is the energy intake impact from parental time with the children and part (b) is the energy output impact.[56] As the energy balance equation shows, when the energy intake effect (part (a)) outweighs the energy output effect (part (b)), there will be energy stored inside the person's body which will contribute to overweight and obesity. Different quality and quantity of parental time spent with children will bring different total marginal effects to children's obesity-related health outcomes. Specific assumptions on the properties of the cross marginal effects on the child's utility level will enable us to derive specific signs as discussed in the theoretical chapter.

6.4. Chapter Summary

This chapter reports detailed empirical estimation results from the triangular system. The empirical analysis shows that a complementary relationship exists between mothers' total income and fathers' non-market work time. The mothers' and fathers' individual total income and individual non-market work time allocation choices display the expected substitution effects. Meanwhile mothers' income and fathers' non-work time allocation choices display a complementary effect. Mothers' time spent with their children is negatively related to their children's BMI scores, which means that mothers'

[56] As discussed in the theoretical chapter (Chapter III), we assume that the energy output is mainly represented by the exercising time.

time spent with their children will improve their children's obesity-related health outcomes. Mothers' work-to-home spillover also plays an important positive role in the BMI production. This is a factor we used to capture the quality of time meaning that it is not just the quantity of time that matters but the quality of time is also important.

The results are not robust across the two alternative estimators (IT3SLS and ITSUR) which may indicate the instruments are possibly weak. Future research should consider the theoretically supported instruments, tests of these instruments, selecting the functional forms and selecting and defining some of the variables (such as work flexibility and work commitment variables).

Another issue that can be examined in future work is to model the numerator and the denominator of the BMI ratio separately to explore potential differences in marginal effects on the two components.

Also, the sample size of this study is relatively small and presents a problem in normality tests. Future work can apply the Anderson-Darling test (recommended for the small samples), normal quantile-quantile plot, and the kernel density plot to test for the normality assumption of the regressions to assess the reliability of the statistical significance. If the normality assumption can not be satisfied, non-parametric methods can be a future study direction.

CHAPTER VII

CONCLUSION AND FUTURE WORK

This chapter will summarize the theory and empirical results of this study and discuss future work.

7.1. Conclusion

Overweight and obesity have become a global epidemic. The increased prevalence of childhood obesity is especially a major concern for society. This study explores the influence of parental time allocation choices on children's obesity-related health outcomes and examines the potential differences between fathers' time marginal effect and mothers' time marginal effect.

The theoretical chapter lays out the theoretical foundation for the analysis. A household with two parents and one child is modeled. Household production theory and the collective household modeling structure are combined in order to capture the dynamics taking place in this multi-person household. Because the focus of our study is the impact of parental choices on the child's obesity-related health outcomes, we only model the child's obesity-related health production. The nutrition literature helps to define two household production functions (the obesity-related health production function and the nutrient intake production function) which generate a nested health production constraint for the model.

The model treats the mother, the father and the child as three separate agents with individual preferences. The two parents' interaction is modeled within the collective model framework by assuming that the two parents will reach Pareto efficient resource allocation between them. In order to capture the dynamics within the household decision-making between parents and the child, the theoretical framework models the parents-child interaction as a two-stage Stackleberg game structure where the child is allowed to have certain decision choices of his/her own. The parents act as the leader by setting up the family rules and making parental decisions first while taking into account the child's possible responses to their decisions. The child is the follower who makes his/her own decisions after observing the parental choices made in the first stage. This game structure allows us to explore the parental influence on the child's health outcome while allowing the child to have some influencing power in the household decision making process.

Based on the theoretical model, an empirical model is derived and presented in the empirical setup chapter. The theoretical model serves to specify the empirical model and the data in a theoretically consistent way.

From the theoretical model derivation, two specifications are derived for the child's obesity-related health production function. One of which, with parental decision variables as its arguments, is selected as our empirical specification. This specification preserves the parental decision variables in the child's obesity-related health production function and enables us to explore parental marginal effects. The specific stage of the theoretical game structure also provides us with several reduced form health input demand functions. The child's health production function is combined with the reduced-form health input demand functions (the parental choice equations) to construct an empirical system, in order to gain both consistency and efficiency.

This constructed empirical system is modified to accommodate the data limitations. However, this modification does not distract us from the focus of this study. The partial effects of parental time allocation on the child's obesity-related health outcome can still be explored.

The identification issue is examined. The empirical system is a general triangular system with cross-equation correlations considered. The IT3SLS is the chosen estimation procedure for consistent and efficient results. In case of weak instruments, both ITSUR and IT3SLS results are presented to access the robustness across these estimators.

The data and summary statistics chapter provides detailed descriptions of data set collection. The sampling process and survey instruments are reported as well.

The data set used in this study covers several aspects of household dynamics, including financial information, parenting styles, sociological factors, family meal practice, nutrient intake pattern, parental time allocation information and children's time allocation information as well as socio-demographics. This complex data covers individual household members and provides us with individual-level parental information and the child health outcome data. The richness of the data set makes it possible to explore parental decision influences and the potential differences between fathers and mothers.

Variable generation and descriptions of the sixteen variables of interest are discussed. The household monthly food expenditure amount is generated by using the decision-maker's reported amount. Individual parental income is the sum of wage income and non-wage income. The parental time allocation variables are generated in a specific way in order to capture working-day time devotion pattern if time diary data reflects information for at least one working day; otherwise the time allocation variables will depict a non-working day pattern. The children's BMI and the parents' individual BMI are calculated according to the BMI definition. The parent's work-to-home spillover is one factor generated using factor analysis. The work environmental variables are all ranking variables which reflect ordinal changes. The other exogenous variables such as peer pressure, socio-demographics, activity level, and parents' decision power variables are discussed as well.

The empirical estimation is performed for three systems: pooled model (pooled over the two age groups with an age dummy added), younger children model (of age 9 to 11), and older children model (of age 13 to 15). Among the results for the children's obesity-related health production function, discrepancies exist across the two estimators (IT3SLS and ITSUR), especially in terms of the numbers of the significant variables.

The mother-related variables have more influence on the children's BMI outcomes as compared to the father-related variables. For both age groups, mothers' time spent with their children has a negative marginal effect on their children's BMI at the 5% significance level. Fathers' time spent with their children has significant negative effect only in the pooled model. Among the work-to-home spillover factors that capture home environment, only mothers' spillover factor positively influences the children's BMI in a statistically significant way. The work-to-home spillover factor is used to capture the quality of time which is as important as quantity. Fathers' BMI does not play any significant role while mothers' BMI consistently has a positive influencing factor in the children's BMI outcomes.

Fathers' or mothers' individual income appears to have a negative effect on fathers' or mothers' own food preparation time allocation. In the older children group, the mothers' own income increases tend to decrease mothers' time with their children. This is consistent with the income and non-working time substitution relationship. The results of the pooled model and the older children model show that fathers' non-market work time and mothers' total income are complementary. There is a complementary relationship between the parents' time and money.

The main contribution of this study is that it develops a general theoretical framework to capture the dynamics between the parents and the child. It takes the parents-child interaction out of the black box. Based on this theoretical model, empirical analysis and future research can be conducted in a theoretically consistent way.

7.2. Future Work

This study laid out a general theoretical framework for exploring parental influences on children's obesity-related health outcomes. The empirical work is just a starting point and leaves a lot of room for future research.

7.2.1. Model specification issues

The empirical results indicate that there are several variables that are not significant. One consideration for future examination can be exploring ways to simplify the model even further. Meanwhile, equation (3.28):

$$(3.28)\quad \frac{\partial H^*}{\partial T_C^i} = \frac{\partial H}{\partial N}\frac{\partial N^*}{\partial T_C^i} + \frac{\partial H}{\partial t_E}\frac{\partial t_E{}^*}{\partial T_C^i} = H_N \underbrace{\frac{\partial N^*}{\partial T_C^i}}_{(a)} + H_{t_E} \underbrace{\frac{\partial t_E{}^*}{\partial T_C^i}}_{(b)},\ i = F, M,$$

shows that there are two components in parental time partial effects on children's health outcomes. Estimating the nutrient intake function and the reduced-form child's exercise time allocation function can be an alternative way to explore the total health effects. This involves utilizing the children's time diary data collected in the project.

The empirical functional forms selection will be another future work direction. Also measurement errors associated with some variables may exist. For example, the model has home environment, work environment and peer pressure indicators and these sociological variables defining issues can be explored further. Also parental time spent with the child variable could be generated in a more specific way to separate the quantity of time and the quality of time.

Another future work consideration is the BMI score. This score is a ratio and can be broken down into two components: weight and height squared. Modeling those two components individually to allow for potentially different marginal effects is another area to explore.

7.2.2. Estimator issues

In the empirical analysis heteroskedasticity tests should be performed to determine whether the general method of moments (GMM) method should be employed or not. The empirical results show discrepancies across the ITSUR and IT3SLS estimators which may indicate that the instruments we have are weak. The auxiliary R-squares do not show that the instruments are weak, however, the reliability of this test is limited. More sophisticated tests should be performed to test the instruments. Non-parametric methods can be employed also.

REFERENCES

Agras, W. Stewart, L.D. Hammer, F. McNicholas, and H.C. Kraemer. "Risk Factors for Childhood Overweight: Prospective Study from Birth to 9.5 Years." *Journal of Pediatrics* 145(2004):20-25.

Amuwo, S., R. Fabian, G. Tolley, and A. Spence, J. Hill. "Child Discipline and Family Decision-Making." *The Journal of Socio-Economics* 33(2004):153-73.

Apps P., and R. Rees. "Taxation and the Household." *Journal of Public Economics* 35(1988):355-69.

____. "Labor Supply, Household Production and Intra-Family Welfare Distribution." *Journal of Public Economics* 60(1996):199-219.

____. "Collective Labor Supply and Household Production." *Journal of Political Economy* 105(1997):179-90.

____. "Household Production, Full Consumption and the Costs of Children." *Labor Economics* 8(2002):621-48.

Baker, D. B. "The Study of Stress at Work." *Annual Review of Psychology* 6(1985):367-81.

Becker, G.S. "A Theory of the Allocation of Time." *The Economic Journal* 75(1965):493-517.

____. *A Treatise on the Family*. Cambridge, MA.: Harvard University Press, 1981.

Bergstrom, T.C. "A Fresh Look at the Rotten Kid Theorem – and Other Household Mysteries." *The Journal of Political Economy* 97(1989):1138-59.

Berman, P., C. Kendall, and K. Bhattacharyya. “The Household Product of Health – Integrating Social-Science Perspectives on Microlevel Health Determinants.” *Social Science and Medicine* 38(1994):205-15.

Blumberg, R.A. “Income Under Male Versus Female Control.” *Journal of Family Issues* 9(1988):51-84.

Bourguignon, F. “The Cost of Children: May the Collective Approach to Household Behavior Help?” *Journal of Population Economics* 12(1999): 503-21.

Bourguignon, F., M. Browning, P.A. Chiappori, and V. Lechene. “Intra Household Allocation: A Model and Some Evidence from French Data.” *Annales D’Economie et de Statistique*. 29(1993): 137-56.

Browning, M., P.A. Chiappori. “Efficient Intra-Household Allocations: A General Characterization and Empirical Tests.” *Econometrica* 66(1998):1241-78.

Burton, P., S. Phipps, and L. Curtis. “All In the Family: A Simultaneous Model of Parenting Style and Child Conduct.” *American Economic Review* 92(2002): 368-72.

Chiappori, P.A. “Rational Household Labor Supply.” *Econometrica* 56(1988):63-90.

____. “ Collective Labor Supply and Welfare.” *The Journal of Political Economy* 100(1992):437-67.

____. “Introducing Household Production in Collective Models of Labor Supply.” *Journal of Political Economy*. 105(1997):191-209.

Chou, S., M. Grossman, and H. Saffer. “An Economic Analysis of Adult Obesity: Results from the Behavioral Risk Factor Surveillance System.” *Journal of Health Economics* 23(2004):565-87.

Cigno, A., A. Luporini, and A. Pettini. “Transfers to Families with Children as A Principal-Agent Problem.” *Journal of Public Economics* 87(2003):1165-77.

Cole, T.J., M.C. Bellizzi, F.M. Flegal, and W.H. Dietz. "Establishing a Standard Definition for Child Overweight and Overweight Worldwide: International Survey." *British Medical Journal* 320(2000):3137-47.

Court, R.H. "Efficient Estimation of the Reduced Form from Incomplete Econometric Models." *The Review of Economic Studies* 40(1973):411-17.

Crocket, L.J., and A.C. Peterson. "Adolescent Development Health: Health Risks and Opportunities for Health Promotion." *Promoting the Health of Adolescents: New Directions for the Twenty-First Century*. New York: Oxford University Press, 1993.

Crouter, A.C., and M.F. Bumpus. "Linking Parents' Work Stress to Children's and Adolescents' Psychological Adjustment." *Current Directions in Psychological Science* 10(2001):156-9.

Cutler, D.M., E.J. Glaeser, and J. M. Shapiro. "Why Have Americans Become So Obese?" *Journal of Economic Perspectives* 17(2003):93-118.

Devine, C.M., M.M. Connors, J. Sobal, and C.A. Bisogni. "Sandwiching It In: Spillover of Work onto Food Choices and Family Roles in Low- and Moderate-Income Urban Households." *Social Science and Medicine* 56(2003):617-30.

Farris, P.W., M.E. Parry, and K.L. Ailawadi. "Structural Analysis of Models with Composite Dependent Variables." *Marketing Science* 11(1992):76-94.

Fenwick, R., and M. Tausig. "The Health and Family-Social Consequences of Shift Work and Schedule Control: 1977 and 1997." in *Fighting for Time: Shifting Boundaries of Work and Social Life*. Edited by Epstein, C. F. and A. L. Kalleberg. 77-110. New York: Russell Sage Foundation, 2004.

Gould, E. "Decomposing the Effects of Children's Health on Mother's Labor Supply: Is It Time or Money?" *Health Economics* 13(2004): 525-41.

Greene, W.H. *Econometric Analysis*. 5th edition. Upper Saddle River, NJ: Pearson Education, Inc. 2003.

Gronau R. "The Intrafamily Allocation of Time: The Value of the Housewives' Time." *The American Economic Review* 63(1973): 634-51.

____. "Leisure, Home Production, and Work – the Theory of the Allocation of Time Revisited." *The Journal of Political Economy* 85(1977):1099-124.

____. "Home Production: A Survey." in *Handbook of Labor Economics*. New York: North Holland 1986.

____. "The Theory of Home Production: The Past Ten Years." *Journal of Labor Economics* 15(1997):197-205.

Hallberg, D., and A. Klevmarken. "Time for Children: A Study of Parent's Time Allocation." *Journal of Population Economics* 16(2003):205-26.

Haveman, R., and B. Wolfe. "The Determinants of Children Attainments: A Review of Methods and Findings." *Journal of Economic Literature*. 33(1995):1829-78.

Hoffman, D.J., and A.L. Sawaya. "Energy Balance". *Encyclopedia of Human Nutrition*. Vol. 2, edited by Sadler, M.J., J.J. Strain, and B. Caballero. 650-58. San Diego: Academic Press, Inc., 1999.

Karlsson, B., A. Knuttson, and B. Lindahl. "Is There an Association between Shift Work and Having a Metabolic Syndrome?: Results from a Population-Based Survey." *Occupational and Environmental Medicine* 58(2001):747-52.

Kinnunen, U., S. Geurts, and S. Mauno. "Work-to-Family Conflict and Its Relationship with Satisfaction and Well-Being: One-Year Longitudinal Study on Gender Differences." *Work and Stress* 18(2004):1-22.

Kmenta, J. *Elements of Econometrics*. 2nd edition. New York: Macmillan Publishing CO., 1986.

Laedwig, B.H. and G.W. McGee. "Occupational Commitment, a Supportive Family Environment, and Marital Adjustment: Development and Estimation of a Model." *Journal of Marriage and Family* 48(1986):821-9.

Lahiri, K., and P. Schmidt. "On the Estimation of Triangular Structural Systems." *Econometrica* 46(1978):1217-21.

Lancaster, K. "A New Approach to Consumer Theory." *Journal of Political Economy* 74(1966): 132-57.

Lundberg, S., R. Pollak, and T. Wales. "Do Husbands and Wives Pool Their Resources? Evidence from the U.K. Child Benefit." *Journal of Human Resources* 32:463-80.

McElroy, M.B. "The Empirical Content of Nash Bargained Household Behavior." *Journal of Human Resources* 25(1990):559-83.

McIntosh, A., G. Davis, R.J. Nayga, J. Anding, C. Torres, K. Kubena, E. Perusquia, G. Yeley, W. You. "Parental Time, Role Strain, and Children's Fat Intake and Obesity Related Outcomes." a report submitted to the Economic Research Service, U.S. Department of Agriculture 2005.

Menaghan, E.G. "Work Experiences and Family Interaction Processes: The Long Reach of the Job?" *Annual Review of Sociology* 17(1991):419-44.

The National Center for Health Statistics and the National Center for Chronic Disease Prevention and Health Promotion. "2 to 20 years: Boys Body Mass Index-for-age percentiles" and "2 to 20 years: Girls Body Mass Index-for-age percentiles." Available at http://www.cdc.gov/growthcharts (assessed July 25th 2005).

Park, J., and G.C. Davis. "The Theory and Econometrics of Health Information in Cross-Sectional Nutrient Demand Analysis." *American Journal of Agricultural Economics* 83(2001):840-51.

Pearlin, L.I. "The Sociological Model of Stress." *Journal of Health and Social Behavior* 30(1989):241-56.

Pitt, M.M., M.R. Rosenzweig, and M.N. Hassan. “Productivity, Health, and Inequality in the Intrahousehold Distribution of Food in Low-Income Countries.” *The American Economic Review* 80(1990):1139-56.

Pollak, R.A., and M.L. Wachter. “The Relevance of the Household Production Function and Its Implications for the Allocation of Time.” *The Journal of Political Economy* 83(1975):255-78.

Prucha, I.R. “The Variance-Covariance Matrix of the Maximum Likelihood Estimator in Triangular Structural Systems: Consistent Estimation.” *Econometrica* 55(1987):977-8.

Rau, R., and A. Triemer. “Overtime in Relation to Blood Pressure and Mood During Work, Leisure, and Night Time.” *Social Indicators Research* 67(2004):51-74.

Rosenzweig, M.R., and T.P. Schultz. “Estimating a Household Production Function: Heterogeneity, the Demand for Health Inputs, and Their Effects on Birth Weight.” *The Journal of Political Economy* 91(1983):723-46.

Silberberg, E., and W. Suen. *The Structure of Economics: A Mathematical Analysis*. 3rd edition. New York: McGraw-Hill Book Co., 2001.

Sturm, R. “The Effects of Obesity, Smoking, and Drinking on Medical Problems and Costs. Obesity Outranks Both Smoking and Drinking in its Deleterious Effects on Health and Health Costs.” *Health Affairs* 21(2002):245-53.

Troiano, R. P, and K. M. Flegal. “Overweight Children and Adolescents: Description, Epidemiology, and Demographics.” *Pediatrics* (1998):497-504.

United States Department of Health and Human Services. “Overweight and Obesity Threaten U.S. Health Gains.” Press Release, December 13, 2001a. Available at http://www.hhs.gov/news/press/2001.html (assessed July 2005).

United States Department of Health and Human Services. *The Surgeon General’s Call to Action to Prevent and Decrease Overweight and Obesity*. Rockville, MD: U.S.

Department of Health and Human Services, Public Health Service, Office of the Surgeon General, 2001b.

United States Department of Health and Human Services. “Obesity Still on Rise, New Data Show.” Press Release, October 8, 2002. Available at http://www.hhs.gov/news/press/2002.html (assessed July 2005).

Vermeulen, F. “Collective Household Models: Principles and Main Results.” *Journal of Economic Surveys* 16(2002):533-64.

Wang, G., and W. H. Dietz. “Economic Burden of Obesity in Youths Aged 6 to 17 years: 1979-1999. *Pediatrics* 5(2002):81-101.

Weinberg, B.A. “An Incentive Model of the Effect of Parental Income on Children.” *Journal of Political Economy* 109(2001):266-80.

World Health Organization (WHO), “Obesity: Preventing and Managing the Global Epidemic”. World Health Organization, Geneva, 2004.

Xie, X.D. “Children and Female Labour Supply Behaviour.” *Applied Economics* 29(1997):1303-10.

APPENDIX

Table 1. Variable Description

Variable	Description	Unit
Dependent Variables (LHS Variables in the triangular system)		
TotExp	Household total food expenditure	Dollars
FatherPrepTime	Father's time spent in food preparation	Minutes
MotherPrepTime	Mother's time spent in food preparation	Minutes
FatherChildTime	Father's time spent with the child	Minutes
MotherChildTime	Mother's time spent with the child	Minutes
KidBMI	The child's Body Mass Index	Kilograms/meters^2
Independent Variables (RHS Variables in the triangular system)		
Economic Variables		
FatherIncome	Father's total income (earned + unearned)	Dollars
MotherIncome	Mother's total income (earned + unearned)	Dollars
FatherTime	Father's total non-work time	Minutes
MotherTime	Mother's total non-work time	Minutes
FatherWorkDay	Father's working day indicator: 1 if it is the working-day pattern; 0 otherwise	0 or 1
MotherWorkDay	Mother's working day indicator: 1 if it is the working-day pattern; 0 otherwise	0 or 1
Sociological Variables		
FatherSpillover	Father's work to home spillover	Factor
MotherSpillover	Mother's work to home spillover	Factor
Peer	Indicator for peer pressure – 1 if there exists peer pressure; 0 otherwise	0 or 1
FatherHR	Father's work hour flexibility – 1 is inflexible; 2 is somewhat flexible; 3 is very flexible	Rank
MotherHR	Mother's work hour flexibility – 1 is inflexible; 2 is somewhat flexible; 3 is very flexible	Rank
FatherDay	Father's work day flexibility – 1 is inflexible; 2 is somewhat flexible; 3 is very flexible	Rank
MotherDay	Mother's work day flexibility – 1 is inflexible; 2 is somewhat flexible; 3 is very flexible	Rank
FatherCommit	Father's commitment to work – 1 to 5 means work is very low priority in life to very high priority in life	Rank
MotherCommit	Mother's commitment to work – 1 to 5 means work is very low priority in life to very high priority in life	Rank
Control Variables		
Age*	Child's age group indicator – 1 if the child is of age 13-15; 0 otherwise	0 or 1
Gender	Child's gender – 1 is for male; 0 is for female	0 or 1
White	Child's ethnicity – 1 is for white; 0 otherwise	0 or 1
Hispanic	Child's ethnicity – 1 is for Hispanic; 0 otherwise	0 or 1
Puberty	Child 's Puberty Stage – 1 if pubescent; 0 for pre-pubescent	0 or 1
Activity1	Child's active exercise frequency in the last 14 days: 1 if 1 to 2 days; 0 if not	0 or 1
Activity2	Child's active exercise frequency in the last 14 days: 1 if 3 to 5 days; 0 if not	0 or 1
Activity3	Child's active exercise frequency in the last 14 days: 1 if 6 to 8 days; 0 if not	0 or 1
Activity4	Child's active exercise frequency in the last 14 days: 1 if 9 or more days; 0 if not	0 or 1
FatherBMI	Father's Body Mass Index	Kilograms/meters^2
MotherBMI	Mother's Body Mass Index	Kilograms/meters^2
D1	Father and mother decision power difference in "whether to buy groceries"	Categories
D2	Father and mother decision power difference in "whether to eat out"	Categories
D3	Father and mother decision power difference in "how much to spend on groceries"	Categories
D4	Father and mother decision power difference in "how much to spend on eating out"	Categories

* The “Age” variable only enters the pooled model (the two age groups are pooled together).

Table 2. Summary Statistics for Pooled Model

Variable	N	Mean	Std. Dev.	Minimum	Maximum
Dependent Variables (LHS Variables in the triangular system)					
TotExp	127	687.85	234.69	210.00	1579.00
FatherPrepTime	127	20.73	25.14	0	114.50
MotherPrepTime	127	64.98	53.90	0	314.50
FatherChildTime	127	78.43	112.10	0	967.00
MotherChildTime	127	90.78	91.51	0	479.50
KidBMI	127	20.72	4.67	14.35	45.10
Independent Variables (RHS Variables in the triangular system)					
Economic Variables					
FatherIncome	127	77696.95	52472.76	1200.00	370000.00
MotherIncome	127	32461.22	33918.37	1125.00	212750.00
FatherTime	127	1001.75	204.65	547.50	1440.00
MotherTime	127	1132.92	214.40	690.00	1440.00
FatherWorkDay	127	0.90	0.30	0	1.00
MotherWorkDay	127	0.80	0.40	0	1.00
Sociological Variables					
FatherSpillover	127	-0.05	0.89	-1.85	2.63
MotherSpillover	127	0.08	0.76	-1.36	2.34
Peer	127	0.10	0.30	0	1.00
FatherHR	127	2.24	0.68	1.00	3.00
MotherHR	127	2.06	0.82	1.00	3.00
FatherDay	127	1.78	0.82	1.00	3.00
MotherDay	127	1.75	0.83	1.00	3.00
FatherCommit	127	2.44	1.04	1.00	5.00
MotherCommit	127	1.91	0.80	1.00	4.00
Control Variables					
Age*	127	0.55	0.50	0	1.00
Gender	127	0.48	0.50	0	1.00
White	127	0.80	0.41	0	1.00
Hispanic	127	0.11	0.31	0	1.00
Puberty	127	0.88	0.32	0	1.00
Activity1	127	0.18	0.39	0	1.00
Activity2	127	0.25	0.44	0	1.00
Activity3	127	0.26	0.44	0	1.00
Activity4	127	0.26	0.44	0	1.00
FatherBMI	127	27.41	3.73	17.63	36.28
MotherBMI	127	25.25	5.16	18.09	46.20
D1	127	0.23	0.83	-2.00	2.00
D2	127	0.10	0.64	-2.00	2.00
D3	127	0.24	0.83	-2.00	2.00
D4	127	0.06	0.76	-2.00	2.00

Variable definitions can be found in Appendix Table 1.

Table 3. Summary Statistics for Children Ages 9 to 11

Variable	N	Mean	Std. Dev.	Minimum	Maximum
Dependent Variables (LHS Variables in the triangular system)					
TotExp	57	676.04	236.25	210.00	1579.00
FatherPrepTime	57	16.06	20.77	0	80.00
MotherPrepTime	57	64.30	43.34	0	202.50
FatherChildTime	57	82.86	78.66	0	419.00
MotherChildTime	57	113.07	95.89	0	479.50
KidBMI	57	19.05	3.75	14.35	28.71
Independent Variables (RHS Variables in the triangular system)					
Economic Variables					
FatherIncome	57	79436.58	57665.00	13356.00	370000.00
MotherIncome	57	29795.18	33296.91	1125.00	160000.00
FatherTime	57	1003.68	218.64	547.50	1440.00
MotherTime	57	1159.52	211.39	825.00	1440.00
FatherWorkDay	57	0.89	0.31	0	1.00
MotherWorkDay	57	0.81	0.40	0	1.00
Sociological Variables					
FatherSpillover	57	-0.06	0.99	-1.66	2.63
MotherSpillover	57	0.07	0.74	-1.36	1.86
Peer	57	0.11	0.31	0	1.00
FatherHR	57	2.25	0.74	1.00	3.00
MotherHR	57	2.14	0.77	1.00	3.00
FatherDay	57	1.93	0.88	1.00	3.00
MotherDay	57	1.77	0.82	1.00	3.00
FatherCommit	57	2.53	1.04	1.00	5.00
MotherCommit	57	1.88	0.78	1.00	4.00
Control Variables					
Gender	57	0.42	0.50	0	1.00
White	57	0.74	0.44	0	1.00
Hispanic	57	0.18	0.38	0	1.00
Puberty	57	0.75	0.43	0	1.00
Activity1	57	0.16	0.37	0	1.00
Activity2	57	0.30	0.46	0	1.00
Activity3	57	0.32	0.47	0	1.00
Activity4	57	0.18	0.38	0	1.00
FatherBMI	57	27.23	3.64	20.08	35.95
MotherBMI	57	24.77	4.50	18.09	41.20
D1	57	0.18	0.76	-2.00	2.00
D2	57	0.12	0.66	-2.00	1.00
D3	57	0.21	0.90	-2.00	2.00
D4	57	0.04	0.63	-1.00	1.00

Variable definitions can be found in Appendix Table 1.

Table 4. Summary Statistics for Children Ages 13 to 15

Variable	N	Mean	Std. Dev.	Minimum	Maximum
Dependent Variables (LHS Variables in the triangular system)					
TotExp	70	697.47	234.68	250.00	1460.00
FatherPrepTime	70	24.54	27.78	0	114.50
MotherPrepTime	70	65.54	61.48	0	314.50
FatherChildTime	70	74.83	133.77	0	967.00
MotherChildTime	70	72.63	84.17	0	442.50
KidBMI	70	22.08	4.92	14.80	45.10
Independent Variables (RHS Variables in the triangular system)					
Economic Variables					
FatherIncome	70	76280.40	48214.52	1200.00	283044.00
MotherIncome	70	34632.14	34501.85	2400.00	212750.00
FatherTime	70	1000.19	194.10	607.50	1440.00
MotherTime	70	1111.26	215.91	690.00	1440.00
FatherWorkDay	70	0.90	0.30	0	1.00
MotherWorkDay	70	0.80	0.40	0	1.00
Sociological Variables					
FatherSpillover	70	-0.05	0.80	-1.85	2.19
MotherSpillover	70	0.09	0.79	-1.31	2.34
Peer	70	0.10	0.30	0	1.00
FatherHR	70	2.24	0.62	1.00	3.00
MotherHR	70	1.99	0.86	1.00	3.00
FatherDay	70	1.66	0.74	1.00	3.00
MotherDay	70	1.73	0.83	1.00	3.00
FatherCommit	70	2.37	1.04	1.00	5.00
MotherCommit	70	1.93	0.82	1.00	4.00
Control Variables					
Gender	70	0.53	0.50	0	1.00
White	70	0.84	0.37	0	1.00
Hispanic	70	0.06	0.23	0	1.00
Puberty	70	0.99	0.12	0	1.00
Activity1	70	0.20	0.40	0	1.00
Activity2	70	0.21	0.41	0	1.00
Activity3	70	0.21	0.41	0	1.00
Activity4	70	0.33	0.47	0	1.00
FatherBMI	70	27.56	3.82	17.63	36.28
MotherBMI	70	25.64	5.64	18.88	46.20
D1	70	0.27	0.88	-2.00	2.00
D2	70	0.09	0.63	-2.00	2.00
D3	70	0.27	0.78	-1.00	2.00
D4	70	0.09	0.86	-2.00	2.00

Variable definitions can be found in Appendix Table 1.

Table 5. The Obesity-Related Health Production Function Results

	Pooled Model		Age 9 to 11		Age 13 to 15	
Variables	**IT3SLS**	**ITSUR**	**IT3SLS**	**ITSUR**	**IT3SLS**	**ITSUR**
Intercept	2.12*	2.09*	1.90*	1.95*	2.38*	2.54*
	(0.32)	(0.22)	(0.44)	(0.30)	(0.41)	(0.40)
TotExp	1.51E-04	1.39E-04*	3.43E-04	2.04E-04*	-6.45E-06	2.40E-05
	(1.56E-04)	(6.70E-05)	(3.03E-04)	(9.20E-05)	(1.86E-04)	(1.13E-04)
FatherPrepTime	1.77E-03	2.96E-03*	1.25E-03	-6.90E-04	8.21E-04	-1.90E-03*
	(2.90E-03)	(5.91E-04)	(4.62E-03)	(1.09E-03)	(2.78E-03)	(7.50E-04)
MotherPrepTime	3.51E-04	5.82E-04*	1.83E-03	9.39E-04	1.07E-03	1.02E-03*
	(8.21E-04)	(2.87E-04)	(2.05E-03)	(5.79E-04)	(7.45E-04)	(3.56E-04)
FatherChildTime	-4.90E-04	-7.00E-04*	-7.20E-04	-4.30E-04	4.00E-05	1.28E-04
	(5.15E-04)	(1.29E-04)	(9.17E-04)	(2.65E-04)	(3.41E-04)	(1.63E-04)
MotherChildTime	-1.00E-04	-6.00E-05	-1.12E-03	-6.50E-04*	-4.40E-04	-1.13E-03*
	(7.46E-04)	(1.75E-04)	(9.91E-04)	(2.52E-04)	(7.45E-04)	(2.63E-04)
FatherSpillover	-0.02	-0.02	0.02	-3.07E-03	-0.03	-0.03
	(0.03)	(0.02)	(0.05)	(0.03)	(0.04)	(0.04)
MotherSpillover	0.05**	0.05**	0.12	0.09*	0.03	0.02
	(0.03)	(0.03)	(0.08)	(0.05)	(0.04)	(0.04)
Peer	0.24*	0.26*	0.24	0.20*	0.30*	0.29*
	(0.08)	(0.07)	(0.16)	(0.09)	(0.09)	(0.10)
Gender	0.03	0.03	0.13	0.12**	-0.04	-0.06
	(0.04)	(0.04)	(0.11)	(0.06)	(0.06)	(0.06)
White	-0.07	-0.08	-0.06	-0.02	-0.05	6.25E-03
	(0.08)	(0.07)	(0.16)	(0.09)	(0.10)	(0.10)
Hispanic	-0.05	-0.05	-0.11	-0.03	-0.20	-0.20
	(0.08)	(0.09)	(0.20)	(0.11)	(0.13)	(0.15)
Age	0.09**	0.08**	-	-	-	-
	(0.05)	(0.04)	-	-	-	-
Puberty	0.08	0.07	0.03	0.05	0.10	0.16
	(0.06)	(0.07)	(0.09)	(0.06)	(0.24)	(0.27)
Activity1	0.21*	0.22*	0.15	0.18	0.16	0.08
	(0.09)	(0.10)	(0.21)	(0.13)	(0.16)	(0.17)
Activity2	0.22*	0.23*	0.04	0.10	0.34*	0.27**
	(0.09)	(0.10)	(0.20)	(0.12)	(0.16)	(0.16)
Activity3	0.23*	0.24*	0.15	0.18	0.20	0.12
	(0.09)	(0.10)	(0.18)	(0.12)	(0.17)	(0.16)
Activity4	0.21*	0.24*	0.15	0.16	0.19	0.09
	(0.11)	(0.10)	(0.17)	(0.13)	(0.17)	(0.16)
FatherBMI	7.24E-03	7.41E-03	7.99E-03	8.15E-03	2.47E-03	1.39E-03
	(6.03E-03)	(5.54E-03)	(0.01)	(8.08E-03)	(7.06E-03)	(8.00E-03)
MotherBMI	0.01*	0.01*	0.02*	0.02*	0.01*	9.60E-03**
	(4.12E-03)	(4.08E-03)	(8.92E-03)	(6.61E-03)	(5.44E-03)	(5.54E-03)
D1	-0.03	-0.03	-1.93E-03	0.01	-0.03	-0.01
	(0.03)	(0.03)	(0.06)	(0.04)	(0.04)	(0.04)
D2	-0.02	-0.02	0.07	0.05	-1.54E-03	-8.60E-04
	(0.04)	(0.03)	(0.07)	(0.04)	(0.05)	(0.05)
D3	-0.02	-0.01	-0.03	-0.04	6.63E-03	0.01
	(0.03)	(0.03)	(0.07)	(0.04)	(0.05)	(0.05)
D4	6.53E-03	3.64E-04	-0.06	-0.02	-2.70E-03	4.69E-03
	(0.03)	(0.03)	(0.10)	(0.05)	(0.04)	(0.04)

Note: Numbers in (.) are standard errors; * : 5% significance level; **: 10% significance level.
Variable definitions can be found in Appendix Table 1.

Table 6. Health Input Demand Results (ITSUR): Pooled Model

Variables	TotExp	FatherPrepTime	MotherPrepTime	FatherChildTime	MotherChildTime
Intercept	325.98	11.67	138.88	59.42	111.23
	(369.33)	(43.46)	(89.41)	(183.79)	(158.79)
FatherIncome	1.70E-03*	-8.00E-05	5.40E-05	3.60E-05	-9.00E-05
	(4.20E-04)	(4.90E-05)	(1.03E-04)	(2.01E-04)	(1.83E-04)
MotherIncome	1.78E-03*	1.93E-04*	-3.80E-04*	1.13E-04	-4.60E-04
	(6.55E-04)	(7.70E-05)	(1.60E-04)	(3.14E-04)	(2.84E-04)
FatherSpillover	65.07*	0.60	5.22	-2.25	21.06*
	(24.73)	(2.95)	(5.86)	(13.41)	(10.38)
MotherSpillover	-5.71	-0.29	-5.87	-14.45	5.56
	(28.80)	(3.43)	(6.81)	(15.68)	(12.07)
FatherHR	-36.83	6.44**	-12.32	-12.06	-10.93
	(33.34)	(3.90)	(8.16)	(15.76)	(14.51)
FatherDay	73.14*	-0.03	10.01	-12.41	3.66
	(29.95)	(3.50)	(7.33)	(14.14)	(13.04)
MotherHR	-21.51	-0.42	-6.39	-11.49	18.76
	(30.60)	(3.58)	(7.49)	(14.44)	(13.32)
MotherDay	14.79	2.29	3.81	25.20	1.27
	(33.05)	(3.86)	(8.09)	(15.56)	(14.40)
FatherCommit	-40.00**	-2.34	-7.02	-2.18	-1.33
	(20.63)	(2.41)	(5.05)	(9.76)	(8.98)
MotherCommit	42.30**	-1.48	13.01*	-30.84*	11.19
	(24.94)	(2.92)	(6.10)	(11.80)	(10.85)
Peer	9.77	-9.94	-18.11	15.94	-3.29
	(70.67)	(8.42)	(16.74)	(38.26)	(29.67)
Gender	-68.25**	1.37	-4.71	19.25	7.58
	(41.14)	(4.91)	(9.71)	(22.55)	(17.20)
White	10.12	12.36	-20.82	2.39	24.62
	(72.87)	(8.69)	(17.26)	(39.51)	(30.58)
Hispanic	140.13	13.08	-13.82	27.49	-15.84
	(89.14)	(10.65)	(21.04)	(48.92)	(37.26)
Age	69.89	4.43	14.02	-9.49	-23.14
	(44.47)	(5.31)	(10.51)	(24.33)	(18.61)
Puberty	-17.26	11.00	-8.54	-17.17	-34.87
	(68.63)	(8.19)	(16.21)	(37.57)	(28.71)

Table 6. Continued

Variables	TotExp	FatherPrepTime	MotherPrepTime	FatherChildTime	MotherChildTime
Activity1	-21.44	2.23	-9.07	61.99	-12.38
	(105.25)	(12.56)	(24.86)	(57.57)	(44.04)
Activity2	-44.51	-2.42	5.85	45.34	-23.26
	(100.80)	(12.04)	(23.79)	(55.34)	(42.13)
Activity3	36.72	-5.19	0.50	32.18	-0.96
	(100.36)	(11.99)	(23.67)	(55.21)	(41.91)
Activity4	-60.48	-8.17	-12.03	56.61	-19.25
	(103.11)	(12.31)	(24.34)	(56.52)	(43.11)
FatherBMI	-5.05	-0.34	-0.86	0.41	-3.45
	(5.73)	(0.68)	(1.35)	(3.13)	(2.40)
MotherBMI	-1.71	-0.40	-1.34	0.07	-0.48
	(4.23)	(0.50)	(1.00)	(2.31)	(1.77)
FatherTime	0.05	0.02	-0.03	0.10	-0.03
	(0.14)	(0.02)	(0.03)	(0.07)	(0.06)
MotherTime	0.15	-0.01	0.07*	0.01	0.09
	(0.14)	(0.02)	(0.03)	(0.07)	(0.06)
D1	-25.81	2.62	-2.70	-10.78	-9.12
	(28.61)	(3.42)	(6.74)	(15.81)	(11.93)
D2	-23.18	-4.08	-0.82	-18.86	30.55*
	(32.95)	(3.93)	(7.78)	(18.06)	(13.78)
D3	88.69*	-0.27	1.98	9.11	15.11
	(30.84)	(3.68)	(7.28)	(16.91)	(12.89)
D4	5.94	3.02	1.15	-4.66	-20.67**
	(27.89)	(3.33)	(6.58)	(15.31)	(11.66)
FatherWorkDay	102.17	-8.32	-15.47	-60.70	-15.33
	(95.24)	(11.13)	(23.32)	(44.93)	(41.47)
MotherWorkDay	38.35	-3.83	-15.56	-3.41	53.14**
	(71.40)	(8.34)	(17.48)	(33.70)	(31.09)

Note: Numbers in (.) are standard errors; * : 5% significance level; **: 10% significance level.
Variable definitions can be found in Appendix Table 1.

Table 7. Health Input Demand Results (ITSUR): Age 9 to 11 Model

Variables	TotExp	FatherPrepTime	MotherPrepTime	FatherChildTime	MotherChildTime
Intercept	283.90	0.71	121.89	319.96	-338.42
	(673.25)	(67.19)	(114.68)	(257.08)	(267.30)
FatherIncome	1.16E-03	-1.60E-04*	-6.00E-05	8.10E-05	1.20E-05
	(7.09E-04)	(7.30E-05)	(1.25E-04)	(2.77E-04)	(2.85E-04)
MotherIncome	3.27E-03*	-3.00E-05	-1.50E-04	2.79E-04	-2.70E-04
	(1.34E-03)	(1.38E-04)	(2.37E-04)	(5.26E-04)	(5.39E-04)
FatherSpillover	4.49	-5.32	-9.40	13.79	23.70
	(51.62)	(5.07)	(8.64)	(19.46)	(20.37)
MotherSpillover	-58.24	6.74	-9.76	41.85	3.55
	(72.70)	(6.95)	(11.81)	(26.82)	(28.39)
FatherHR	44.30	6.84	-0.23	11.45	-17.43
	(71.21)	(7.45)	(12.76)	(28.24)	(28.81)
FatherDay	66.89	3.32	-4.60	-15.29	4.39
	(54.12)	(5.66)	(9.69)	(21.45)	(21.89)
MotherHR	30.39	7.18	-0.11	-26.20	31.27
	(57.77)	(6.00)	(10.27)	(22.78)	(23.30)
MotherDay	-133.32	-7.06	20.80	57.79**	-55.46
	(87.07)	(8.96)	(15.34)	(34.09)	(35.00)
FatherCommit	-7.62	0.10	-3.78	-27.50	4.42
	(51.95)	(5.42)	(9.29)	(20.57)	(21.00)
MotherCommit	60.65	-9.98*	3.28	-29.32	-6.57
	(47.28)	(4.84)	(8.28)	(18.43)	(18.96)
Peer	-282.36**	-9.55	-12.84	88.44	-114.21*
	(145.61)	(13.90)	(23.63)	(53.66)	(56.84)
Gender	-17.87	14.62	-3.10	31.71	46.84
	(96.67)	(9.32)	(15.87)	(35.92)	(37.88)
White	-176.26	19.65	19.76	39.35	-41.59
	(134.35)	(12.59)	(21.37)	(48.81)	(52.10)
Hispanic	-118.08	5.21	35.13	48.96	-58.98
	(159.98)	(15.05)	(25.55)	(58.29)	(62.12)
Puberty	-8.74	8.92	-14.70	1.26	-3.89
	(95.08)	(8.97)	(15.23)	(34.71)	(36.95)

Table 7. Continued

Variables	TotExp	FatherPrepTime	MotherPrepTime	FatherChildTime	MotherChildTime
Activity1	-164.81	33.58*	10.22	115.69**	-32.54
	(176.19)	(16.44)	(27.88)	(63.77)	(68.20)
Activity2	-318.67**	20.74	37.10	52.37	-24.28
	(166.11)	(15.52)	(26.33)	(60.19)	(64.33)
Activity3	-233.35	10.42	23.24	57.97	-78.91
	(173.61)	(16.32)	(27.70)	(63.20)	(67.38)
Activity4	-232.59	8.45	6.67	25.01	-39.64
	(177.70)	(16.52)	(28.02)	(64.15)	(68.70)
FatherBMI	-0.75	0.25	-1.58	-0.44	-1.41
	(11.39)	(1.07)	(1.81)	(4.13)	(4.41)
MotherBMI	-4.56	-0.96	1.48	1.11	-3.09
	(11.04)	(1.06)	(1.80)	(4.08)	(4.32)
FatherTime	0.17	0.01	-0.07	0.05	0.31*
	(0.28)	(0.03)	(0.05)	(0.11)	(0.11)
MotherTime	0.39	-6.65E-03	0.03	-0.23*	0.25*
	(0.29)	(0.03)	(0.05)	(0.11)	(0.11)
D1	-20.46	0.49	5.94	5.60	-39.90**
	(55.33)	(5.12)	(8.69)	(19.91)	(21.36)
D2	-161.24*	-4.65	7.36	21.67	-9.51
	(74.16)	(7.18)	(12.22)	(27.63)	(29.10)
D3	-52.32	-6.93	-3.35	-9.96	-6.33
	(58.18)	(5.47)	(9.29)	(21.19)	(22.59)
D4	173.11	2.97	8.06	-57.00	76.09**
	(107.90)	(10.64)	(18.14)	(40.81)	(42.64)
FatherWorkDay	131.38	-5.76	-44.30	-18.15	97.03
	(151.96)	(15.75)	(26.97)	(59.84)	(61.26)
MotherWorkDay	-123.81	-0.50	-25.51	-83.08	50.13
	(149.57)	(15.54)	(26.60)	(59.00)	(60.35)

Note: Numbers in (.) are standard errors; * : 5% significance level; **: 10% significance level.
Variable definitions can be found in Appendix Table 1.

Table 8. Health Input Demand Results (ITSUR): Age 13 to 15 Model

Variables	TotExp	FatherPrepTime	MotherPrepTime	FatherChildTime	MotherChildTime
Intercept	17.36	69.97	248.81	198.08	371.58
	(614.87)	(99.92)	(215.67)	(472.55)	(275.05)
FatherIncome	2.75E-03*	3.00E-05	1.39E-04	-4.20E-04	7.00E-05
	(5.73E-04)	(9.20E-05)	(2.01E-04)	(4.41E-04)	(2.54E-04)
MotherIncome	4.35E-04	2.43E-04**	-6.10E-04*	1.20E-04	-7.70E-04*
	(7.89E-04)	(1.26E-04)	(2.78E-04)	(6.10E-04)	(3.44E-04)
FatherSpillover	41.44	-0.77	10.95	-6.94	1.74
	(35.01)	(6.00)	(11.99)	(26.23)	(16.90)
MotherSpillover	-7.81	-3.89	-3.68	-26.93	-17.58
	(32.78)	(5.65)	(11.20)	(24.50)	(15.93)
FatherHR	-63.06	2.66	-28.22**	17.96	-45.94*
	(43.60)	(6.94)	(15.42)	(33.80)	(18.93)
FatherDay	70.51**	-7.76	22.67	2.32	5.92
	(39.36)	(6.25)	(13.93)	(30.54)	(17.01)
MotherHR	27.97	-0.37	-5.27	-42.47	21.44
	(36.96)	(5.87)	(13.09)	(28.69)	(15.97)
MotherDay	-25.99	6.65	-0.14	60.36**	-15.83
	(42.35)	(6.73)	(14.99)	(32.86)	(18.33)
FatherCommit	-22.64	-1.98	-20.31*	7.31	-5.16
	(24.80)	(3.94)	(8.77)	(19.23)	(10.74)
MotherCommit	29.74	-4.92	23.98*	12.09	-14.39
	(31.86)	(5.06)	(11.28)	(24.73)	(13.77)
Peer	70.99	-9.09	-35.90	-4.94	36.23
	(83.37)	(14.38)	(28.47)	(62.30)	(40.56)
Gender	-133.39*	1.73	-12.67	34.71	-33.04
	(47.04)	(8.16)	(16.02)	(35.05)	(23.06)
White	-50.51	7.19	-32.65	36.23	37.20
	(97.99)	(16.59)	(33.75)	(73.90)	(46.48)
Hispanic	92.55	-9.10	-28.80	47.14	-9.99
	(137.05)	(23.40)	(47.03)	(102.94)	(65.74)
Puberty	113.92	8.99	-25.21	-223.29	-37.13
	(233.82)	(40.14)	(80.02)	(175.13)	(113.05)

Table 8. Continued

Variables	TotExp	FatherPrepTime	MotherPrepTime	FatherChildTime	MotherChildTime
Activity1	39.12	-25.07	-21.13	0.53	-13.45
	(153.44)	(26.10)	(52.75)	(115.46)	(73.23)
Activity2	157.06	-23.67	-16.78	-3.93	1.96
	(135.81)	(23.34)	(46.45)	(101.66)	(65.77)
Activity3	109.28	-28.89	-21.36	-25.45	-1.18
	(148.33)	(25.29)	(50.93)	(111.48)	(71.04)
Activity4	-2.09	-31.07	-29.74	39.55	-28.77
	(142.90)	(24.38)	(49.05)	(107.37)	(68.48)
FatherBMI	-3.32	0.23	-0.87	-2.23	-1.63
	(7.38)	(1.26)	(2.54)	(5.55)	(3.53)
MotherBMI	-0.75	-0.08	-2.49	-1.80	-2.17
	(4.86)	(0.83)	(1.67)	(3.65)	(2.34)
FatherTime	-0.01	0.03	-0.05	0.01	-0.19*
	(0.20)	(0.03)	(0.07)	(0.16)	(0.09)
MotherTime	0.31**	-0.04	0.09	0.17	0.12
	(0.18)	(0.03)	(0.06)	(0.14)	(0.08)
D1	-56.56**	3.79	2.55	-22.70	3.40
	(34.08)	(5.87)	(11.64)	(25.48)	(16.56)
D2	26.52	-6.90	-10.66	-55.37**	15.89
	(42.19)	(7.28)	(14.40)	(31.52)	(20.53)
D3	131.21*	2.26	0.86	60.59*	8.66
	(39.52)	(6.79)	(13.52)	(29.59)	(19.12)
D4	1.91	9.74**	-3.70	-30.46	-22.78
	(31.25)	(5.38)	(10.67)	(23.36)	(15.18)
FatherWorkDay	71.52	-8.29	11.33	-248.24*	-34.78
	(124.88)	(19.89)	(44.16)	(96.79)	(54.25)
MotherWorkDay	104.60	-23.13	-17.11	118.48	66.85
	(95.00)	(15.15)	(33.58)	(73.60)	(41.33)

Note: Numbers in (.) are standard errors; * : 5% significance level; **: 10% significance level.
Variable definitions can be found in Appendix Table 1.

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